CIHM
Microfiche
Series
(Monographs)

ICMH
Collection de
microfiches
(monographies)

Canadian Institute for Historical Microreproductions / Institut canadien de microreproductions historiques

Technical and Bibliographic Notes / Notes techniques et bibliographiques

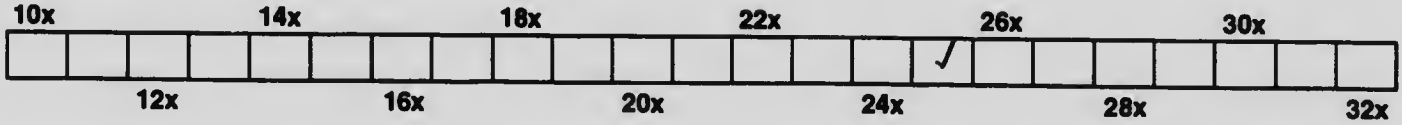
The Institute has attempted to obtain the best original copy available for filming. Features of this copy which may be bibliographically unique, which may alter any of the images in the reproduction, or which may significantly change the usual method of filming are checked below.

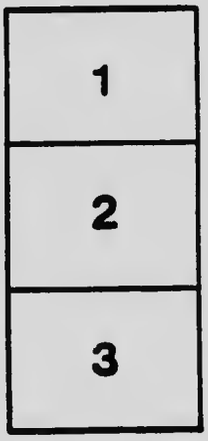
- [x] Coloured covers / Couverture de couleur
- [ ] Covers damaged / Couverture endommagée
- [ ] Covers restored and/or laminated / Couverture restaurée et/ou pelliculée
- [ ] Cover title missing / Le titre de couverture manque
- [ ] Coloured maps / Cartes géographiques en couleur
- [ ] Coloured ink (i.e. other than blue or black) / Encre de couleur (i.e. autre que bleue ou noire)
- [ ] Coloured plates and/or illustrations / Planches et/ou illustrations en couleur
- [ ] Bound with other material / Relié avec d'autres documents
- [ ] Only edition available / Seule édition disponible
- [ ] Tight binding may cause shadows or distortion along interior margin / La reliure serrée peut causer de l'ombre ou de la distorsion le long de la marge intérieure.
- [ ] Blank leaves added during restorations may appear within the text. Whenever possible, these have been omitted from filming / Il se peut que certaines pages blanches ajoutées lors d'une restauration apparaissent dans le texte, mais, lorsque cela était possible, ces pages n'ont pas été filmées.
- [ ] Additional comments / Commentaires supplémentaires:

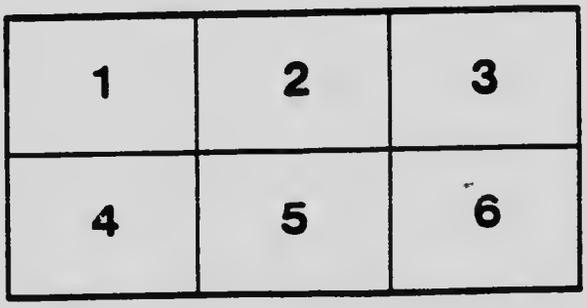
L'Institut a microfilmé le meilleur exemplaire qu'il lui a été possible de se procurer. Les détails de cet exemplaire qui sont peut-être uniques du point de vue bibliographique, qui peuvent modifier une image reproduite, ou qui peuvent exiger une modification dans la méthode normale de filmage sont indiqués ci-dessous.

- [ ] Coloured pages / Pages de couleur
- [ ] Pages damaged / Pages endommagées
- [ ] Pages restored and/or laminated / Pages restaurées et/ou pelliculées
- [x] Pages discoloured, stained or foxed / Pages décolorées, tachetées ou piquées
- [ ] Pages detached / Pages détachées
- [x] Showthrough / Transparence
- [ ] Quality of print varies / Qualité inégale de l'impression
- [ ] Includes supplementary material / Comprend du matériel supplémentaire
- [ ] Pages wholly or partially obscured by errata slips, tissues, etc., have been refilmed to ensure the best possible image / Les pages totalement ou partiellement obscurcies par un feuillet d'errata, une pelure, etc., ont été filmées à nouveau de façon à obtenir la meilleure image possible.
- [ ] Opposing pages with varying colouration or discolourations are filmed twice to ensure the best possible image / Les pages s'opposant ayant des colorations variables ou des décolorations sont filmées deux fois afin d'obtenir la meilleure image possible.

This item is filmed at the reduction ratio checked below / Ce document est filmé au taux de réduction indiqué ci-dessous.

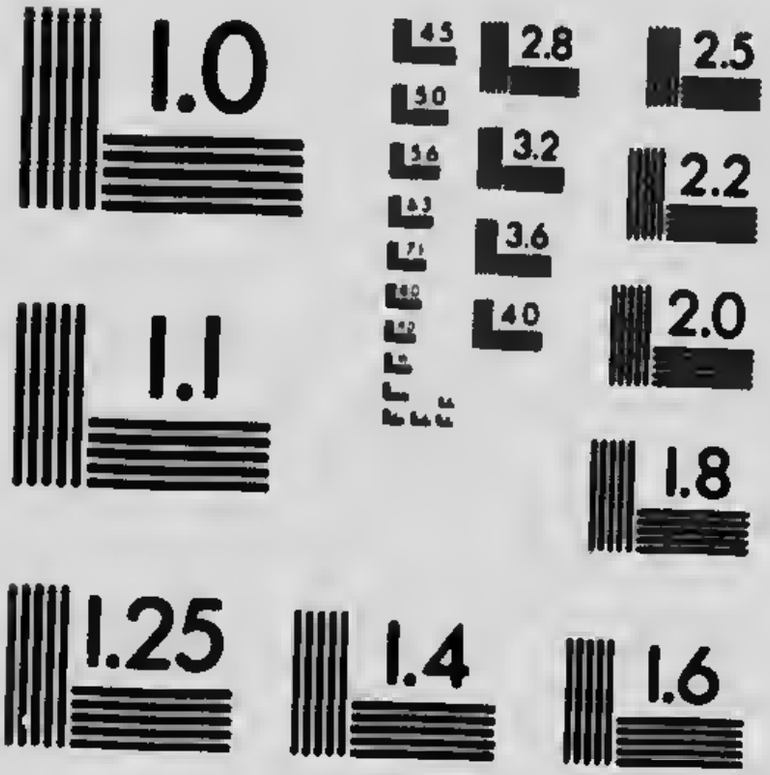






MICROCOPY RESOLUTION TEST CHART

(ANSI and ISO TEST CHART No. 2)



APPLIED IMAGE Inc

1653 East Main Street
Rochester, New York 14609 USA
(716) 482 - 0300 - Phone
(716) 288 - 5989 - Fax

TIDE LEVELS

AND

DATUM PLANES

IN

EASTERN CANADA

From determinations by the Tidal and Current Survey
up to the year 1917.

W. Bell Dawson, M.A., D.Sc., M.Inst.C.E., F.R.S.C.,
Superintendent of Tidal Surveys.

Published by the Department of the Naval Service
Ottawa, Canada.

OTTAWA
J. de LABROQUERIE TACHÉ
PRINTER TO THE KING'S MOST EXCELLENT MAJESTY
1917

TIDE LEVELS

AND

DATUM PLANES

IN

EASTERN CANADA

From determinations by the Tidal and Current Survey
up to the year 1917.

W. Bell Dawson, M.A., D.Sc., M.Inst.C.E., F.R.S.C.,
Superintendent of Tidal Surveys.

Published by the Department of the Naval Service
Ottawa, Canada.

OTTAWA
J. de LABROQUERIE TACHÉ
PRINTER TO THE KING'S MOST EXCELLENT MAJESTY
1917

28186—1

Deac. 1985

LOCALITIES,

FOR WHICH TIDE LEVELS ARE GIVEN.

D

TIDE LEVELS AND DATUM PLANES

in *Eastern Canada.*

By W. Bell Dawson, M.A., D. Sc., M. Inst. C.E., F.R.S.C.

Superintendent of the Tidal and Current Survey.

In connection with the Survey of Tides and Currents, much valuable information has been obtained regarding tide levels, and a number of Bench-marks have been established at the various tidal stations both in Eastern Canada and on the Pacific coast. This Survey, which is under the Ministry of Marine and is now a branch of the Naval Service, has for its primary object the determination of the time-relations of the tide, and the turn of tidal currents, for the information of mariners. The determination of levels is thus quite collateral to the object which the department has in view, although it is necessary within certain limits; because at the principal tidal stations, it is essential to maintain a uniform datum level for the reduction of the observations. It is highly desirable that this should correspond with the chart datum; but the soundings even on harbour charts are not taken more closely than the nearest quarter foot, and in tide tables the height of the tide is given to the nearest tenth of a foot. It is thus a very different matter to maintain truly accurate levels based on a limit of accuracy in the individual observations of 0.01 of a foot in height.

It was thus evident that the tidal observations would be greatly enhanced in value and much information of importance to engineers would be secured, by obtaining reliable levels and by establishing Bench-marks at all tidal stations at which registering instruments were placed, even for a few months. The additional work involved was therefore undertaken from the outset in 1894, when the present superintendent took charge, after the initial or tentative stage. The endeavour has also been made to correlate the new levels with any that were already established by others or any previously existing datum. These tide levels have proved very serviceable for wharf construction, harbour improvements, dredging, city drainage, and other works which have a relation to the tide.

At the date when the Tidal Survey was organized, there was no general system of levelling in Canada. The best general datum or plane of reference for works of construction as well as for natural altitudes, is the mean level of the sea, which can only be determined by tidal observations. It is this datum which is adopted in most countries for general reference. The importance of Mean Sea level for this purpose was recognized by the Tidal Survey before the geodetic or precise levelling of recent years was commenced; as will be seen from the following extract from a publication by the Superintendent, issued in 1903: "Eventually as the observations are continued, the value of Mean Sea level, extreme tide levels, and other factors of importance, are determined with

reference to the local Bench-mark. Although there is as yet no general system of levels in Canada, these results are of service locally in the meantime; and they also furnish a basis for any more extended geodetic levelling which may be undertaken."

This foresight is now bearing fruit, as the determinations of Mean Sea level which are now available at our principal harbours, are being utilized as a basis by the Public Works department for their extended levels, and by the Interior department for precise levels in Eastern Canada as well as in British Columbia. For the extensive levels in Prince Edward island, which are being carried along its railway system by the department of Government Railways, a basis was afforded by the determination of Mean Sea level at Charlottetown, obtained during the last five years.

Accuracy of Mean Sea level.—There is a slight variation in the value of Mean Sea level from year to year, which is undoubtedly actual, and not due to any want of accuracy in the observations. A comparison between Halifax and New York, on the open coast of the Atlantic, shows an evident correspondence in the variation at the two places in the same years of the series. The outstanding uncertainty in the value, as determined at Halifax from a limited series of years, does not probably exceed 0.013 of a foot, judging by a comparison with a twenty-year average at New York.

Such an uncertainty is much less than the probable error on even 100 miles of precise levelling; and it therefore indicates that the levels themselves should be checked by Mean Sea level determinations at the tidal stations which the lines of levels may connect. This method is adopted in the levelling systems of India and the United States; any accumulated error in long land lines being eliminated at the shore stations where the elevation of Mean Sea level is accepted as absolute, if determined from the average of several years. It is also correct in theory, as the surface of the sea represents the spheroid of the earth, which is the curved datum plane for continental areas.

Relation to Geological stability.—In addition to the value of Mean Sea level as a basis for extended levelling, it also affords the only sure method of detecting any change in the elevation or subsidence of the coast, from a Geological point of view. A re-determination of Mean Sea level after a period of years would show whether there is any appreciable change. The localities at which Mean Sea level is now determined, are well adapted for this purpose; as they cover the whole of our Eastern coasts from southern Nova Scotia to Belle Isle strait; and the determinations are equally comprehensive on our Pacific coast.

Staff.—The staff of the Survey for the investigation of the currents as well as for the tidal observations, levels and reductions, has never been large. In the early years, the various branches of the work were carried out by the Superintendent with the assistance of Messrs. H. M. Mackay, G. G. Hare and R. B. Angus. Some others, employed for shorter periods or merely temporarily, had little to do with the determination of tide levels, which we are now considering. The present staff, in addition to the Superintendent, consists of Messrs. S. C. Hayden, H. W. Jones and R. B. Lee; with Miss S. L. Howell as stenographer. This staff overtakes the field work, as well as the office reductions and the preparation and publication of the three sets of Tide Tables issued annually. In the outside service, there are also six tidal observers at the principal tidal stations

in Eastern Canada. and six on the Pacific coast, who are residents of the various localities where these tidal stations are established.

Tidal branch.—The general system, in this branch of the work, has been to establish principal tidal stations for reference, which are kept in operation throughout the year; and in each summer season to erect temporary stations by which the tides of some region are brought into relation with a principal station. The time of the tide and the rise, at all our harbours, are thus being referred to the principal stations for which Tide Tables are published. It is evidently desirable to reduce the number of principal stations by making them serve for as large a region as possible. The great variety in the types of tide on the coasts of Canada however, have made it necessary to maintain the numbers above indicated.

Methods and appliances.—A description of the equipment required for a principal tidal station to enable it to work continuously, summer and winter, will be found in "Tide Gauges in Northern climates and Isolated situations," by the present writer. (Proc. Inst. C.E., London; Vol. CXLIX, Part 3.) The registering instrument consists essentially of a vertical cylinder that revolves in 24 hours, and carries a diagram or graduated sheet on which the tide is recorded by a pencil that rises and falls with the tide. The pencil is actuated by a float placed in a vertical tide pipe, and the range of the tide is suitably reduced by gearing. A tide curve is thus produced on the diagram; and as the tide is an hour later each day, the curves can run on for a half a week, or a week without confusion. This also gives better results in the reductions, as it affords a large number of comparative observations for the same diagram.

The two essentials for the observations, are some means of obtaining correct time which is often the chief difficulty, and some plane of reference for height. As regards height and levels, a Bench-mark is established for reference and its elevation taken as 100.00 feet. A tide scale is placed with its zero well below the lowest possible tides, so that the registering tide gauge when set to correspond with it, will be sure to record all low waters. The elevation of the zero of this scale is accurately known with reference to the Bench-mark; but it is to be specially emphasized that its zero does not represent any tide level, as these are all unknown at the outset. The scale may be liable to settlement, or it may be carried away and replaced in the course of years. The only essential is that the elevation of the zero should at all times be known without uncertainty.

Such open scales can be used at the permanent stations on the Pacific coast, and also at all summer stations; but in Eastern Canada a sight gauge or floating scale has to be used, within the shelter of the tide house which protects the registering instrument. It is essentially a graduated rod standing on a float which rises and falls in a second vertical tide pipe, in accordance with the tide. Where the range of the tide is too great to use a vertical rod, a metal tape passing over a pulley is substituted. The true elevation of the zero of this sight gauge is determined from its total length measured from the line of flotation on the float, and the elevation of the fixed gnomon or index point used in reading it. A description of the two types of sight gauge and the various kinds of metal tapes that have been tried, might be interesting; but it will suffice to say that by means of instrumental levels and measurements taken every year, to check any variation through settlement or other causes, the elevation of its

zero is at all times known within 0.01 or 0.02 of a foot. In case of a winter accident, the measurements made next season may have to be carried back to the date of the accident; but if any uncertainty still remains, the observations themselves have to be thrown out as valueless, at least for the determination of Mean Sea level; though time results may hold good.

The setting of the registering instrument is kept in accord with the sight gauge, and any difference between them is ascertained by comparative readings taken simultaneously; just as the time errors are ascertained by comparisons with the true time. By a system of averaging these comparisons, the true relation of the zero of the diagram on the recording instrument to the zero of the sight gauge is ascertained. From this in turn, the true elevation of the zero line of each diagram relatively to the Bench-mark is definitely known. It is of course desirable to maintain these relations as constant as possible for convenience; but so long as the observer takes the comparisons as directed, any change is at once evident; and the reductions are controlled by the headquarters staff and by the levels taken at the annual inspection of the tide station.

Datum levels.—The reference level to be first determined, and required for working purposes, is the Low-water datum, based upon low water at Spring tides, as will be explained. This can usually be determined after a few months, or from the first year of observations. The Low-water datum then becomes known as a reading on the face of the tide scale, and as an elevation with reference to the Bench-mark. This enables the datum to be ruled as a line across the face of each diagram obtained by the recording instrument. In doing so, any difference with the tide scale or the sight gauge as shown by the comparisons, is allowed for.

We now have on our series of diagrams, a datum line at a constant elevation throughout, from which all levels of high and low water or extreme tides can be measured, and brought into relation with the Bench-mark if desired. If we are dealing with a summer station, the tide scale has now served its purpose. It is evident that the setting of this scale was purely technical, and the elevation of its zero had no significance except for office reductions. We do not therefore publish the elevations of tide scales or sight gauges as a rule; as they might be misunderstood to represent some tide level or datum, which is not the case.

The determination of Mean Sea level can now be made by measuring the hourly ordinates of the tide from this constant datum level to the tide curve. It is determined for a period of one continuous year at a time; and being thus based on the height of the tide at every hour, day and night, the value for the year is the average of 8,760 individual measurements. Such an average is quite reliable to the third decimal of a foot. From the analytical standpoint, the result is the height above datum of a horizontal line which bisects the area of the tide curve; and this may therefore be accepted as the geometrical definition of Mean Sea level.

The elevation of Mean Sea level is thus the last outcome of tidal observations as regards levels. At our principal stations in Eastern Canada and on the Pacific coast, its determination is based on a series of five to sixteen complete years, so that the final value obtained may be considered as highly accurate. At a number of other localities, tidal record is available for an approximate determination.

Low-water datum.—This datum differs essentially from Mean Sea level in not representing a constant elevation. It is a plane of reference at half the range of the tide below the mean level of the sea. In an estuary, it is thus a plane that is inclined from the mouth to the head as the range of the tide increases. Around the southern half of Nova Scotia, it is a spiral plane, from 3 feet below Mean Sea level at Halifax to 25 feet below, in the arms of the Bay of Fundy.

The only justification for such a plane of reference is its great convenience to the mariner, in showing the least amount of water available in bays and channel-ways under the influence of the tide. It is therefore almost universally used as a chart datum; and by using the same datum as the zero level in tide tables, the extra depth due to the rise of the tide is made evident.

The reason for adopting a Low-water datum at all, makes it desirable that it should represent the lowest level to which the tide usually falls. As it happened that the tides were first investigated on the coasts of Europe and in the North Atlantic, it was supposed that their main variation in range was from springs to neaps with the moon's phases; as this is the dominant variation in that region, where the lowest usual level is at spring tides. The Low-water datum came therefore to be defined as "Low Water at ordinary Spring tides;" the term *ordinary* probably indicating astronomical tides undisturbed by storms. We thus start with a definition which is quite inapplicable to the world generally.

The reason of this is that the variation in range from springs to neaps is only one out of the three variations that occur from astronomical causes. The other two are variation with the moon's distance, and inequality in the two tides of the day which is in accord with the moon's declination. In some regions, as in the Bay of Fundy, the variation in the range of the tide with the moon's distance from perigee to apogee is distinctly greater than the variation from springs to neaps. Of all the variations from the true average range of the tide, the greatest that occurs is due to diurnal inequality in regions where this feature is the dominant one. It also happens that the average level of high water may remain nearly constant, leaving practically the whole of the inequality to affect the low-water level. This occurs both in Northumberland strait and the Strait of Georgia, the two regions in Canada in which this inequality is most highly developed; although there are also localities where low water remains nearly constant and the inequality chiefly affects high water.

On the coasts of Canada, there are examples of every type of tide found anywhere; and the variations of low water as affecting the question of the most suitable Low-water datum, can be well illustrated from Canadian tides. To show what the variation may amount to, we give the following classified examples with approximate values. They correspond with the three astronomical types of tide already indicated; known as the synodic, the anomalistic, and the declinational.

(1) Difference in level between low water at springs and neaps at Father Point in the St. Lawrence estuary, 3 feet. (This tide is not notably affected by other inequalities. The spring range is 13 feet.)

(2) Difference in the level of low water with the moon's distance when perigee and apogee fall at the springs; at the head of the Bay of Fundy in Minas

Basin, 5 feet. (Low water at the two spring tides of the month may differ by this amount in several successive months. Average spring range, 45 feet.)

(3) Difference in the level of low water on the two tides of the day. At Sand Heads in the Strait of Georgia, 8 feet. At Charlottetown in Northumberland strait, 3½ feet. (This difference occurs whenever the moon is in high declination, north or south of the equator. It is accentuated when the sun is also in high declination at the solstices, when the extreme tides of the year occur.)

To take the average level between these extremes as a Low-water datum for tides of the second and third types, would not be more unreasonable than to take the average level between springs and neaps for the first type. In all three cases, many of the tides would fall below such a datum, and often to the extent of several feet. A datum for chart purposes which is thus too high, is misleading to the navigator, as he would so often find less water than the chart indicated; and if adopted as the zero level for tide tables, there would be too many low waters with negative values.

It is therefore only for the tides of the first type, and in regions where the other inequalities are small enough to be negligible, that the average level of low water at both the spring tides of the month can reasonably be taken as datum. This is the limitation of the original definition regarding low water at ordinary spring tides.

For the second type of tide, it is necessary to take the average level of the lower of the two spring tides of the month; and in extreme cases, where the semi-monthly inequality amounts to several feet, the average should include the low waters at perigee springs only.

For the third type of tide, it is best to take the average of the lowest low water in each month of the year, irrespective of the cause or combination of causes that make it the lowest. This method was adopted by the Public Works engineers in the early days on the Pacific coast, in determining a datum for dredging. With such a datum, the tides in the vicinity of the solstices are the only ones likely to fall below it.

A datum determined by these methods will be satisfactory in being sufficiently low for the requirements of charts and tide tables and for the dredging of channels; and it will be found to accord well with the practice of hydrographic surveyors. But the practical difficulty is that the limitation to one tide a month is too meagre a basis for a good average, except perhaps at principal tidal stations where observations for a year or more are available. Even where springs and neaps are the only marked feature, there is usually enough inequality between the two tides of the month to make it desirable that the datum should correspond with the lower of the two. At summer stations especially, where only four or five month's tidal record is obtained, the limitation to one low water in the month would be too great a restriction, especially if any storm tides have to be omitted as untrustworthy.

It is therefore better to take the average level of the lowest low water at each spring tide during the observations, and to allow a margin below this for the other variations. This level is termed "Average level of Low Water at Spring tides," which is used consistently with this meaning throughout these tide levels in regions where springs and neaps are dominant. The way will

be explained later by which a suitable margin, between this level and the Low-water datum, is arrived at.

For high water, the average level of the highest high water at each Spring tide is termed similarly "Average level of High Water at Spring tides," and the height of this level above the datum is the "Spring Rise," which affords the best means of comparing the amount of tide at different localities, or the increase in height with its progress.

In determining a Low-water datum for secondary stations on the Pacific coast, where the tides are of the declination type, a special average level for low water is used to bring the local datum into direct correlation with the principal station. The average is taken from simultaneous observations for the same series of months. It was thus only at the principal stations, where a long tidal record is available, that a primary determination of the Low-water datum was necessary. This method enables a consistent datum level to be carried throughout a region where the tide is of the declination type and the variation in the level of low water is very great; making the series of observations available at a secondary station too short for an independent determination. An average level for high water is also obtained; and both a low and high water average level being thus correlated with the principal station, a comparison of the difference of level between them affords a ratio with the rise at the principal station; and this enables the height of any tide at the secondary station to be found from the rise above datum at the principal station as given in the tide tables. The ratio is readily applied when once it is determined.

In Eastern Canada, the only principal tide stations at which a Low-water datum was found already referred to a Bench-mark during the Admiralty surveys, were Halifax and Quebec. At St. John, N.B., a datum had also been established, but the Bench-mark was destroyed in the great fire of 1877. These two available datums were adopted from the outset; and wherever there was opportunity to make comparison with an Admiralty datum in any of the regions where summer stations were established, the endeavour was made to keep new datums consistent with it; as well as to maintain harmony between the datum at the principal stations and local datums in the same region.

From such comparisons in regions where springs and neaps are dominant, and from datums established by this Survey which had proved to be satisfactory for tide table purposes, the margin of allowance was arrived at, between the standard level of Average Low Water as already defined, and the Low-water datum. This margin runs from about 0.50 foot to 1.50 feet, according to the range of the tide. This may be considered as an allowance for the variation between the two spring tides of the month, or for the diurnal inequality, as these do not usually occur together; making it seldom that the spring tides fall below datum. For both variations to concide, the moon's perigee must fall at t springs, and its maximum declination must occur near the same date; a with this co-incidence there will be negative values in the tide tables.

We have thus explained in some detail the method of dealing with tides in which the springs and neaps are the dominant feature, and the other variations although relatively small cannot be ignored, as the tides of Eastern Canada are largely of this type. It may also be said in general, that the datum level arrived at by this method, and by the others described, is found to be in good

accord with the Admiralty practice in chart surveys. We will also give so examples to show the relation of the datum to observed low water in differe regions.

When the datum is decided upon, it can always be defined with refere to a local Bench-mark, or Mean Sea level where this is known.

Range of the tide.—The truest comparison of tides with each other is means of the range from low water to high water, under any given conditio This is the actual amplitude of the tidal undulation, and is independent of a plane of reference, either at low water or at Mean Sea level. But for this ve reason, it has little relation to definite tide levels.

General Geodetic and Precise levelling.—The system of levels carried by the Public Works department, runs primarily from Halifax to Father Poi and determinations of Mean Sea level at both these principal stations have be made available by the Tidal Survey. This line of levels, running across three provinces of Nova Scotia, New Brunswick and eastern Quebec, is th checked at both ends. From this north and south line, 480 miles in leng as a base, the mean level of the sea can be carried westward to the upper Lawrence, where it connects with the New York system at the head of La Champlain and in the region of the Great Lakes.

From this base line of levels, branch lines have been carried eastward the Geodetic survey to points on the east coast of New Brunswick, along Chal bay to Gaspé, and all along the south shore of the St. Lawrence estuary. T elevations of the various local Bench-marks already established by the Ti Survey, are therefore given wherever the Geodetic survey has now made conn tion with them.

In the coast region of the Maritime provinces, the Dominion Observato in the Interior department has carried levels through southern New Brunswi and Nova Scotia from the frontier of Maine to the Gut of Canso. A datu for this line was obtained by the connection of its western end with Mean S level at New York by a land line nearly 500 miles in length, running throu the intermediate States. Another line runs across this, from Halifax to Moncto and a third line follows the Nova Scotia shore from Halifax to Yarmouth, which a check is obtained at the Yarmouth end by a determination of Me Sea level there, based on one complete year of observation by this Surve Several other lines of levels run by the Dominion Observatory, lie further inlan and do not connect the tidal stations on the coast with each other.

In Prince Edward island, an extended series of levels is being carried alo the railway lines by the Government Railways department. These lev are based on Mean Sea level as determined at Charlottetown from five comple years of tidal observation there.

On the long stretch of coast, 645 miles in length, from the Saguenay to Be Isle strait, there are no continuous levels; although tide levels are now kno locally at a series of stations in this region. There is also a well-determin value for Mean Sea level already available at the far eastern end, at Forte bay in Belle Isle strait.

D

Quebec.

The Low-water datum to which the soundings on the Admiralty chart of Quebec harbour are reduced, was recorded by a Bench-mark, and is thus defined by a note on the harbour chart:—"The soundings are reduced to the mean level of Low Water ordinary Spring tides; or 28 feet below a Bench-mark cut in the stonework on the East side of the principal gateway to the Marine and Fisheries department." The tide gauge for Quebec was erected in 1893 at the masonry dry dock on the Lévis side; and instrumental levels had previously been carried over from the Admiralty Bench-mark to this dock by Mr. R. Steckel of the Public Works department. The Bench-mark at the dry dock is a copper plug driven horizontally into the face of the second altar step from the top, on the west side of the dock, near the inner end; and it is numbered LXXIV in Mr. Steckel's series. The elevations of the two Bench-marks, referred to his own datum, are as follows:—Admiralty Bench-mark, 27·039 feet; Bench-mark LXXIV, 21·616 feet. The Low-water datum for the tidal observations from 1893 onward, was therefore taken as 22·58 feet below the Bench-mark, to correspond with the Admiralty datum.

The recent levels by the Geodetic survey in 1915, make the difference between these Bench-marks to be 5·38 feet, instead of 5·42 according to Mr. Steckel's determination; and according to this new value, the Low-water datum at the tide gauge differs by 0·04 of a foot from the Admiralty datum as defined by the Bench-mark on the Quebec side.

Comparison of Datum levels.—The various datum levels used at Quebec are defined by the following relations, which enable them all to be brought into relation to the Admiralty datum.

Royal Engineers' datum. Adopted as mean tide level in 1864, and used as the datum for their contoured plan of Quebec; at 7·76 feet above Mr. Steckel's datum, as determined by him from the Royal Engineers' Bench-marks.

Datum for the St. Lawrence, established by Mr. R. Steckel in 1880-82, and defined by the following elevations:—

Elevation of the Admiralty Bench-mark	27·04	feet.
Elevation of coping of the Louise dock	24·02	feet.

Datum of the Quebec Harbour Commissioners. Defined as 24·00 feet below the coping of the Louise dock. The elevation of the Admiralty Bench-mark above this datum is 27·05 feet, as determined by Mr. St. George Boswell, Chief Engineer, Quebec Harbour Commissioners.

	Elevation.
Bench-mark, defining the Admiralty datum	28·00
Royal Engineers' datum, being their determination for Mean Sea level at Quebec	8·72
Steckel's datum at 27·04 below the Admiralty Bench-mark. (See his Report of 1891.)	0·96
Quebec Harbour Commissioners' datum from three evaluations as follows: (1) from Steckel's determination of the actual zero of their scale, on the Harbour Commissioners' wharf, 0·94 (2) From elevation of Admiralty Bench-mark, from levels by St. George	

Boswell, 0·95 .3) Defined as 24 feet below coping of the Louise dock, 0·98. Mean accepted.....
Admiralty Low-water datum.....

At the Lévis dry dock there are two scales of feet cut on the mas one outside and the other inside of the dock gate, which are intended to the height of the water above the masonry sill of the dock. The tide g was set with reference to the outside scale from 1893. The feet as cut o masonry are not quite accurate however, and to find the true position of zero, the elevations of five of the feet in the vicinity of half tide were determi and from the mean of these, the elevation of the zero was ascertained reference to the Bench-mark. The surface of the masonry sill, or invert o dock, differs slightly from the zero level.

In the observations, the sight gauge or floating scale in the tide h was set correctly with the masonry scale; but it was found best to trust t sight gauge for comparisons, as it could always be read to the nearest hundr of a foot, whereas the masonry scale only gave half feet, and in the wi months it was blocked with ice. The true length of the sight gauge from line of flotation on the float, was always correctly known throughout the y of the observations; and its length was re-determined in case of breakag renewal. In the whole series of years from 1894 to 1916, the zero of the s gauge varied only from 100·13 to 99·97, for which allowance was made in redu the observations.

The following levels are based on an elevation of 100·00 feet for the zero of the outside masonry scale, corresponding to 130·36 for Bench-m LXXIV. This Bench-mark is 15·63 feet above Mean Sea level, as carried f Halifax and checked at Father Point, on the line of levels of the Geodetic sur

	Elev
Admiralty Bench-mark on Marine and Fisheries building in Quebec; at 5·38 feet above Bench-mark LXXIV as determined by the Geodetic survey; and 28 feet above Admiralty Low-water datum.	135
Coping of the Dry Dock at Lévis; average level taken near the dock gate.....	132
Bench-mark LXXIV on masonry of Dry Dock, as above described; at 30·36 feet above zero of outside scale.....	130
Extreme High Water in the season from May to November, during the years 1901 to 1916; in 1914 on November 20.....	130
Average level of High Water in the two seasons of 1900 and 1908 from May to October. From thirteen Spring tides in each season..	126
Mean Sea level, or local half tide; as determined from sixteen complete years of tidal observation; at 8·613 feet above Low-water datum. (See details given below.).....	116
Average level of Low Water at thirteen Spring tides in the season of 1908.....	108
Average level of Low Water at thirteen Spring tides in the season of 1900.....	108
Low-water datum, maintained since 1893; being also the zero level for the height in the Quebec Tide Tables. (Latest levels make this 0·04 foot higher than the Admiralty datum.).....	107

D

Extreme Low Water in the season from May to November, during the years 1901 to 1916; in 1913 on November 1	106·80
Surface of masonry sill, or invert of the dock	100·04
Zero of scale on masonry, outside the dock gate, determined as explained	100·00

Mean Sea level at Quebec.—As found from the observations at the dry dock at Lévis; determined from the hourly ordinates of the tide, above the Low-water datum at elevation 107·78 during the following complete years of observation:—

	Feet
One year, from January 1894 to January 1895	8·655
" January 1895 to January 1896	8·509
" February 1896 to February 1897	8·491
" February 1897 to February 1898	8·648
" March 1898 to March 1899	8·563
" March 1899 to March 1900	8·575
" March 1900 to March 1901	8·542
" March 1901 to March 1902	8.690
" July 1902 to July 1903	8·763
" July 1903 to July 1904	8·624
(Admission to gauge impeded by accumulation of mud.)	
One year, from April 1905 to April 1906	8·517
" April 1906 to April 1907	8·444
" April 1907 to April 1908	8·749
" April 1908 to April 1909	8·642
" April 1909 to April 1910	8·870
" April 1910 to April 1911	8·523
For sixteen years. General average	8·613

The result for Mean Sea level or half tide as determined at the Lévis dry dock, is thus 8·61 feet above the Low-water datum, or 13·97 feet below Bench-mark LXXIV. The actual elevation in the series already given is 116·39 which enables it to be brought into relation with any other tide level or datum. If correlated with levels on the Quebec side, the assumption is involved that there is no slope in the Low-water datum from the Quebec side to the Lévis dry dock.

River slope at Quebec.—Mean Sea level or local half tide at Quebec as found from the hourly ordinates of the tide, is undoubtedly higher by about 1½ feet than the true mean level of the ocean. An evaluation of this difference from connection of levels made at Rouse's Point with the New York lines, was fully stated in a Paper by the Superintendent of the Tidal Survey, published by the Canadian Society of Civil Engineers in November, 1908. The difference then given was 1·46 feet, and when corrected in 1914 for later determinations in the series of connections, it becomes 1·52 feet above Mean Sea level at New York. The through levels of the Geodetic survey give the following result, from Mean Sea level at Halifax as checked at Father Point:—

Bench-mark LXXIV at Lévis dry dock; elevation above Mean Sea level according to the Geodetic levels of 1915 .....

Mean Sea level or local half tide as determined by the Tidal Survey relatively to this Bench-mark.....

Half tide above oceanic Mean Sea level .....

Exceptional tides.—The following table gives the extreme levels of t for a series of sixteen years; and it is confined to the open season from to November 30, because in the mid-winter months and also when the ice out in the spring, any partial obstruction of the river may cause irregula the levels which is not due to true tidal influence. The low stage of the in the river towards autumn has also an effect; and in the Low-water seri extremes are therefore in the autumn.

Exceptional High Waters, above the Low-water datum.				Exceptional Low Waters, below the Low-water datum.		
Date.			Height.	Date.		H
1901.	May	19	20·90 feet.	1901.	Oct.	28	—0·0
1902.	June	8	21·20 "	1904.	Sept	23	—0·2
1903.	July	27	20·30 "	1905.	Nov.	22	—0·1
1904.	May	16	20·50 "	1906.	Oct.	8	—0·1
1905.	May	19	21·10 "	1907.	Oct.	22	—0·3
1906.	Nov.	16	21·90 "	1908.	Oct.	13	—0·0
1907.	Nov.	7	22·25 "	1909.	Oct.	26	—0·0
1908.	May	31	21·00 "	1911.	Nov.	20	—0·0
1909.	Nov.	25	20·65 "	1912.	Oct.	11	—0·2
1910.	May	10	20·30 "	1913.	Nov.	1	—1·0
1911.	May	2	20·80 "	1914.	Nov.	19	—0·5
1912.	Nov.	25	21·75 "	1915.	Sept.	23	—0·4
1913.	Oct.	2	20·10 "	1916.	Nov.	25	—0·9
1914.	May	11	20·50 "				
1915.	May	1	20·90 "				
1916.	May	18	20·70 "				

NOTE.—In years not given, tide did below datum during the season.

THE ST. LAWRENCE ABOVE QUEBEC.

Special features of the tide.—From St. Augustin, where the first bars Quebec occur, to the head of tide water at Lake St. Peter, the tides show ur features; and their behaviour is also modified by the variation in the river during the season. The mean level of the water in the river falls grad from the high stage in spring to the low stage in autumn. The usual e in level from this cause is five feet from April to October.

The following are the most noteworthy features of the tide concisely s with special reference to the lower stages of the river and the tidal low w as these are of most importance in regard to the depth available for naviga

(1). At Point Platon and above, Low Water at Neap tides falls lower Low Water at Spring tides. At ordinary stages of the river, the lowest Waters of the month thus occur shortly after the moon's quarters. At the hi

flood stages, the lowest Low Waters may be long after the moon's quarters, and they may even be as late as the date of the next new or full moon. (At Quebec, L.W. at Neap tides is on the average 2¾ feet above the level of L.W. at Spring tides, as usual. The reversal of their relative levels takes place in the neighbourhood of St. Augustin; being somewhat further up or down the river as the stage varies with the season.)

(2). Next in importance to the Springs and Neaps, is the variation in height caused by the change in the moon's distance. It is accordingly possible for Low Water at one of the Neap tides of the month, to be a foot and a half lower than at the other. There is also a distinct diurnal inequality at times when the moon's declination is high. This may amount to a difference of more than one foot in the height of the two Low Waters of the same day. The inequality in the height of successive High Waters is much greater. Such variations should not be attributed to wind disturbance, as they are strictly astronomical.

(3). Throughout the river, at Quebec and above, the range of the tide is reduced by the high stage of the river. The range thus becomes greater during the season, as the river falls; and accordingly, the decrease in the available depth at High Water, is not so great as the fall in the stage of the river would indicate.

Tide levels.—The tide levels here given, are based upon two series of simultaneous observations taken by Mr. R. Steckel, C.E. in 1886 and 1887. The are for a period of one lunar month in the autumn when the river is at its lowest stage, and one lunar month in the following spring at the high stage of the river. The effect of the variation in the river level upon the tidal undulation, will be seen in the tables below. The heights are all reduced to the uniform datum established by Mr. Steckel, which extends from Quebec to Montreal; and they thus indicate the slope of the river as well as the amplitude of the tide. The observations are given in full detail in his Report, dated November, 1891, entitled "Water Levels, River St. Lawrence, between Quebec and Montreal;" issued by the Public Works department.

The locality in the river which is of most importance in regard to the depth available for navigation, is at Cap à la Roche; where there is a bar of rock and heavy boulders, on which dredging has been done for several years. Tidal observations were obtained here during the two seasons of 1905 and 1906 with a registering tide gauge; and during the four previous seasons, from 1901 to 1904, the Semaphore record was obtained, which is equivalent to scale readings at every six inches, in the rise and fall of the tide. From these six seasons, the time-differences with Quebec have been obtained, and their variations determined, by which the Tide Tables for Cap à la Roche are calculated.

In the tables below, the mean High Water at Spring tides is found by taking the highest average for the two tides of any one day, as well as the mean of the two Spring tides in the lunar month. In this way, both the diurnal and semi-monthly inequalities are eliminated, which gives better comparative values, when each period of observation is limited to a single month. The Low-water value is not always at the Springs, as the lowest levels occur nearer to the Neaps in the upper part of the river, as already explained; but the inequalities are eliminated in the same way. The values given in the column headed, Greatest difference of level, serve to indicate the decrease in range as the tidal undulation

ascends the river. A marked change, according to the stage of the river, o at the Richelieu rapids, between Point Platon and Grondines. The observa at Quebec were taken at the dry dock on the Lévis side; which is the location as the Tidal Survey gauge now has.

The datum established by Mr. Steckel, to which all the heights are redu is at 0·96 foot above the Admiralty Low-water datum at Quebec, as show the comparison of datum levels already given. The Low-water levels at Qu and St. Nicholas have negative values at the low stage, until the slope o river brings their elevation above datum.

HIGH STAGE OF THE RIVER IN THE SPRING.

TIDE LEVELS during one lunar month, May 4 to June 3, 1888.

Localities.	Extreme High Water.	Mean H. W. at Spring Tides.	Mean of lowest Low Waters.	Extreme Low Water.	Greate differe of lev
Champlain	25·92	25·61	21·42	20·67	5·
Batiscan	25·25	24·46	20·00	19·47	5·
Cap à la Roche	24·36	23·05	16·56	15·94	8·
Grondines	23·83	22·32	13·74	13·02	10·
Point Platon	23·05	21·17	7·46	6·36	16·
St. Nicholas	20·99	18·92	3·09	2·45	18·
Quebec	20·18	17·64	1·36	0·50	19·

LOW STAGE OF THE RIVER IN THE AUTUMN.

TIDE LEVELS during one lunar month, Oct. 11 to Nov. 10, 1887.

Localities.	Extreme High Water.	Mean H. W. at Spring Tides.	Mean of lowest Low Waters.	Extreme Low Water.	Greate differe of lev
Champlain	19·25	18·46	14·50	14·35	4·
Batiscan	18·75	17·65	13·18	13·01	5·
Cap à la Roche	18·49	17·33	9·38	9·22	9·
Grondines	18·34	17·30	6·96	6·64	11·
Point Platon	18·67	17·14	2·39	2·14	16·
St. Nicholas	17·89	16·58	−0·29	−0·57	18·
Quebec	18·40	16·43	−1·06	−1·32	19·

ST. LAWRENCE ESTUARY.

In the St. Lawrence estuary the variation in the height of the tide, nex the change from Springs to Neaps, is due to the moon's distance. The diu inequality is not highly developed Care is thus required when determin average Low Water, to base the value on tides which are balanced at the oppo halves of the month; for the level of Low Water at Spring tides may differ by feet when perigee and apogee fall at the new and full moon.

D

Average Low Water and datum.—At the end of the season, the average level of Low Water at Spring tides is worked out, and a datum is decided upon with reference to it; or if a Low-water datum has already been established for the locality, its relation to this average is ascertained. The height of the datum on the tide scale in either case becomes known, and the datum can be ruled as a line across the face of each diagram obtained by the recording instrument. The table given below illustrates this, in accordance with the general methods already described. It shows the levels of Low Water first as readings on the diagram or tide scale, and next as reduced to the Low-water datum.

This table is for Orignaux Point which is quite below any river influence on the tide levels. There is an Admiralty datum here, defined by a Bench-mark; and the zero of the tide scale was connected with it by instrumental levels, thus enabling all tide levels to be brought to definite elevations.

Locality and Date in 1900	Low Water at Springs.		Moon's phases and distance.
	Height on tide scale.	From L.W. datum.	
Orignaux Point, June 26	4·50 feet.	+0·59 foot.	New Moon. Mean distance.
" July 15	4·35 "	+0·44 "	Full Moon.
" July 28	5·30 "	+1·39 feet	New Moon.
" Aug. 13	2·83 "	−1·08 "	Full Moon. Perigee.
" Aug. 25	5·80 "	+1·89 "	New Moon. Near Apogee.
" Sept. 10	1·75 "	−2·16 "	Full Moon. Perigee.
Average Low Water	4·09 feet.		
Height of datum on scale	3·91 "		
Average L.W. above datum		+0·18 foot	

Average Low Water at Spring tides, is thus the average level of the lowest Low Water at each Spring tide during the season, when balanced for the semi-monthly inequality as explained. This expression is used consistently with this meaning throughout the tide levels. Average High Water at Spring tides, is similarly the average level of the highest High Water at each Spring tide.

Grosse Isle—One of the right tidal stations in the St. Lawrence estuary at which simultaneous observations were obtained in 1900. The tidal record obtained here, extended from May 4 to October 15.

At Grosse Isle there are two wharves on the side of the island facing the channel of the river. The Admiralty Bench-mark is a ring bolt, let into the rock at High-water mark, situated 200 feet west of the West wharf. The level of Low Water at ordinary Spring tides, to which the soundings on the chart are reduced, is at 21 feet 10 inches below this Bench-mark.

In using this ring bolt as a Bench-mark, the point taken for reference was the top of the eye through which the ring passes.

A second Bench-mark consists of a copper bolt driven vertically into a flat piece of rock at the High-water mark; at 53 feet northeast of the ring bolt, and 70 feet south of the Quarantine building. Marked "C—B.M.—T"

	Elev
Top of cap at outer end of West wharf	10
Highest known High Water at the Spring tides of February, 1894, as marked at the time by Captain Langlois, who resides on the island. The more trustworthy marks give the level of this high water as 102·85 or 103·33. Best mean value	10
Bench-mark.—Top of eye of ring bolt, as above described. Elevation adopted	10
Second Bench-mark.—Top of copper bolt as above described	9
(Elevation above Mean Sea level, as determined by water transfer from the South shore, by the Geodetic survey, 12·42.)	
Exceptional High Water recorded in the season of 1900, on September 12, during a gale	9
Highest level of High Water undisturbed by storms during the season of 1900	9
Average level of High Water at ten Spring tides during the season	9
Admiralty Low-water datum, at 21 feet 10 inches below the ring bolt	7
Lowest level of Low Water recorded during the season of 1900, on September 9	7

The maximum range of the tide on the whole length of the St. Lawre occurs at Grosse Isle; as the true head of the estuary is in this vicinity, below Orleans island. It is thus of interest to note that the average ris Spring tides is 19·75 feet above the Admiralty Low-water datum, and greatest known rise in February, 1894, is 24·84 feet above that datum.

Crane island wharf.—Tidal observations were obtained here in the sea of 1908. They were taken simultaneously at L'Islet; the object being obtain data for the time and height of the tide in Beaujeu channel, which between these two localities. This is the only dredged channel below Que and the tide scale used by the Ship Channel survey for the dredging was pla at Crane island wharf.

The average level of Low Water, as observed simultaneously at eight Spr tides during the season, was used to transfer the original Admiralty Low-wa datum across from L'Islet. The Low-water datum for the dredging was t found to be 0·26 foot below the Admiralty datum at L'Islet; and it has theref been adopted at both localities as the datum from which to measure the rise of tide, as it corresponds better with the series of datums in this region. The dat is thus correlated also with the dredging in Beaujeu channel.

As regards this method of transfer, the following remarks may be made. T average range at Spring tides, as shown by the simultaneous observations 1908, increases from 18·18 feet at L'Islet to 18·98 feet at Crane island. As th may still be some river slope as far as L'Islet, the level of Low Water at the t localities should be more nearly the same than the level of High Water, when t range is increasing. The datum as determined at Crane island should theref be closely the same in relation to the range of the tide, even if it differs in act elevation from L'Islet by some part of the above difference.

Tidal Survey Bench-mark. A horizontal groove cut on the stone foundati at east corner of lightkeeper's house, about one foot from the ground. The lett "T.S." are chiselled below it.

D

Bench-mark of the Ship Channel survey. A nail in a tree behind a shed at head of wharf. Elevation 26·46 feet above the zero of the tide scale; and 1·35 feet above the Tidal Survey Bench-mark.

	Elevation.
Bench-mark as above described. Elevation adopted	100·00
Average level of High Water at eight Spring tides during the season; 18·98 feet above Admiralty Low-water datum	94·13
Admiralty Low-water datum, as transferred from L'Islet	75·15
Zero of scale of feet placed by Ship Channel survey; the zero being the Low-water datum for the dredging	74·89
Lowest Low Water during the season of 1908, on October 14	74·45
Bottom of channel as dredged; at 30 feet below the Low-water datum given by the zero of the scale	44·89

Beaujeu channel.—The resulting tide levels for the dredged channel, as taken from Crane island wharf and L'Islet, above and below, and referred to the Low-water datum of the Ship Channel survey, are as follows:—

	Feet.
High Water at Spring tides; based upon the average height of eight Springs observed in 1908, at Crane island wharf	19·24
Intermediate value for Beaujeu channel	19·00
High Water at Spring tides; based upon the average height of the same eight Springs in 1908, at L'Islet	18·43
Admiralty Low-water datum, at 0·26 of a foot higher than the datum of the Ship Channel survey	0·26
Ship Channel survey, Low-water datum	0·00
Bottom of Beaujeu channel, dredged to 30 feet below this datum	−30·00

From comparisons of the rise of the tide at both L'Islet and Crane island wharf with Quebec, at both Spring and Neap tides, the rise in Beaujeu channel will not be less for any tide than in the Quebec Tide Tables.

L'Islet.—Tidal observations were obtained here during the simultaneous series of 1900, from May 12 to October 15; as well as in 1908 as already mentioned.

The Admiralty Bench-mark is a broad arrow cut into the face of a vertical rock, at 30 feet east of the inner end of the pier at L'Islet. The level of Low Water at ordinary Spring tides, to which the soundings on the chart of the Traverse are reduced, is at 34 feet below this Bench-mark. Its elevation above Mean Sea level, as determined by the Geodetic survey, is 26·05 feet.

On the face of the same rock, a little lower down and to the westward, a copper bolt is let in horizontally, and is marked G.B.M. (Government Bench-mark) No. CLIV.

The levels at L'Islet are as follows:—

	Elevation.
Admiralty Bench-mark, as above. Elevation adopted.	100·00
Copper bolt above described; cross-line at the centre	98·29
Exceptional High Water recorded in the season of 1900, on September 12, during a gale	86·10

Highest level of High Water undisturbed by storms during the season of 1900	8
Average level of High Water at eight Spring tides during the season of 1908	8
Average level of High Water at eleven Spring tides during the season of 1900	8
Admiralty Low-water datum, at 34 feet 0 inches below their Bench-mark.	6
Low-water datum of the Ship Channel survey, transferred as already explained from their tide scale at Crane island wharf	6
Lowest level of Low Water recorded during the season of 1900, on September 11	6
Lowest level of Low Water, season of 1908, on September 11	6

The soundings on the Admiralty chart of "The Traverses" which ext to Goose island, are referred to the Admiralty datum at L'Islet. In two sea in 1900 from May to October and in 1908 from July to November, there were Spring tides that fell below that datum; the lowest of these being 0·68 of a below it, which corresponds with the elevations above given.

On this chart, the Low-water datum is also defined as 29 feet 5½ inches b the base of North tower of L'Islet church. This second Bench-mark was established by Commander Maxwell during the Admiralty surveys; but it is very reliable as a Bench-mark. The reference to it, and the connection of " Bench-marks made by the Geodetic survey, would give 66·29 as the elev the Admiralty datum, or 3½ inches higher than the other. This cannot b accurate as the reference to the Bench-mark on the shore, as above given. second Bench-mark was no doubt established for greater security, to preserve important datum in the Traverses.

Orignaux Point.—This is one of the eight tidal stations in the St Lawre estuary at which simultaneous observations were obtained in 1900. The t observations obtained here, extended from June 22 to September 11.

The Admiralty Bench-mark at this point, is a broad arrow cut on a s vertical face of rock, facing the east; at a distance of 37½ feet west of the in end of the wharf at this point; which is termed in the Railway time tab Rivière Ouelle wharf. The correct level of the Admiralty Low-water datun 23 feet 1½ inches below this Bench-mark. Its elevation above Mean Sea le as determined by the Geodetic survey, is 13·61 feet.

On the first of the recent series of charts for the St. Lawrence estuary, iss by the Hydrographic survey, entitled "Mal baie to Goose island," Admiralty Low-water datum is adopted, as above defined. The lower part of Traverses is comprised in the area of this chart.

	Elevat
Top of cap at the head of the wharf at Orignaux Point	105
Bench-mark as above. Elevation adopted	100
Extreme High Water; said to reach the top of sheet piling protection, about nine feet below top of cap. Corresponding elevation	96
Highest level of High Water recorded during the season of 1900, on July 15 and August 11	95

(The extreme High Water of September 12 was not recorded here.)	
Average level of High Water at six Spring tides during the season of 1900	95·22
Admiralty Low-water datum; at 23 feet 1½ inches below the Bench-mark. Also adopted by the Hydrographic survey	76·88
Extreme Low Water; said to lay bare the mud at inside angle of wharf behind the head. Corresponding elevation	74·90
Lowest level of Low Water recorded during the season of 1900, on September 10	74·75

Cap à l'Aigle.—On the north shore of the St. Lawrence, immediately east of Murray bay. Tidal observations were taken as scale readings for one month in July and August of 1905.

A Bench-mark, established by the Hydrographic survey, is a broad arrow cut on a flat faced boulder at 150 feet north-east of Cap à l'Aigle wharf. This Bench-mark appears to have been destroyed subsequently, when all boulders were removed for filling the crib work of the new wharf.

The Low-water datum used for the reduction of the soundings of the Hydrographic survey in this vicinity, is at 17 feet 7 inches below the Bench-mark. The two Spring tides observed, indicate that this level corresponds well with the datum on the south shore.

The tide levels, relatively to the Low-water datum, are as follows:—

	Feet.
Bench-mark as described; at 17 feet 7 inches above datum	17·58
Average level of High Water at the two consecutive Spring tides observed	17·45
Average level of Low Water at these two Spring tides	0·50
(Extreme Low Water, not ascertained as the observations were not continued throughout the season.)	
Low-water datum	0·00

Rivière du Loup.—One of the eight tidal stations in the St. Lawrence estuary at which simultaneous observations were obtained in 1900. These observations extended from June 30 to October 17. Further observations were obtained in the season of 1905, for two months from July to September; taken as scale readings by the Hydrographic survey.

The Admiralty Bench-mark is a broad arrow cut into a vertical face of rock, facing north; at 100 feet westward of the centre of the flag pole which stands on the highest ground of Rivière du Loup Point, near the wharf. The elevation of this Bench-mark above Mean Sea level, as determined by the Geodetic survey, is 16·98 feet. The Admiralty Low-water datum is at 24 feet 2 inches below this Bench-mark. The datum used by the Hydrographic survey for this region is 26 feet below the Bench-mark.

The Admiralty datum is too high; as it is not as low as the average of the Low Waters at Spring tides in 1900. On the other hand, the Hydrographic datum is too low. To obtain a Low-water datum at a level, relatively to average Low Water at Springs, which corresponds with the datum elsewhere in the estuary, a foot higher should be taken; or 25 feet below the Bench-mark. This is necessary in the present comparisons, to make the rise of the tide consistent and comparable throughout the estuary.

	Eleva
Bench-mark as above. Elevation adopted	10
Exceptional High Water recorded in the season of 1900, on September 12, during a gale	9
Highest level of High Water, undisturbed by storms, during the season of 1900, on July 14	9
Average level of High Water at six Spring tides during the season of 1900	9
Admiralty Low-water datum, at 24 feet 2 inches below the Bench-mark	7
Average level of Low Water at the six Spring tides during the season of 1900	7
Low-water datum adopted, to correspond with the datum elsewhere, as above explained	7
Lowest level of Low Water observed during the two months in the season of 1905, on September 1	7
Low-water datum of the Hydrographic survey at 26 feet below the Bench-mark	7
Lowest level of Low Water recorded during the 3½ months in the season of 1900, on September 10	7

Tadoussac.—This is one of the eight tidal stations at which simultane observations were obtained in 1900, from July 6 to September, 15 Furt observations were secured in 1907 and 1908, with a registering tide gauge, co-operation with the Hydrographic survey. The record obtained extends fr June to December in 1907, and from June to November in 1908.

A Bench-mark was established in 1907 by the Hydrographic survey, on the cliff opposite the north-west corner of the steamer wharf at L'Anc l'Eau, which is the landing for Tadoussac. It is a broad arrow cut in outl on the rock, and marked "B.M. 07". The Low-water datum adopted by t Hydrographic survey for this region, is at 19·20 feet below this Bench-ma The Tidal Survey observations of 1900 were correlated with these later obs vations by means of average low water in the three seasons, as follows:—

1907. Average Low Water at 14 Spring tides undisturbed by storms; above Low-water datum	0·52
1908. Average Low Water at 12 Spring tides, above datum	0·58
Low-water datum for 1900, taken at the mean of 0·55 foot below average Low Water at Spring tides in that season	0·55

This method may be explained more definitely, as it has been necessary use it elsewhere. The average level of Low Water in 1900 was found to be 4· on the tide scale as set in that season. The datum was taken as 0·55 fo below this, or at 4·20 on the tide scale, and a datum line was ruled across t face of the tide diagrams at this level, with allowance for any difference with t tide scale on any diagram, as shown by the comparisons. This line represent the Low-water datum at 19·20 feet below the Bench-mark, or elevation 80·8 and the tide levels were reduced with reference to it, for correlation with t other seasons.

	Elevation.
Bench-mark as above described. Elevation adopted	100·00
Exceptional High Water in the season of 1900, during the gale of September 12	99·35
Highest level of High Water undisturbed by storms in the season of 1900, on September 11	98·20
Average level of High Water at four Spring tides during the season of 1900	97·07
Average level of High Water at twelve Spring tides during the season of 1908	97·71
Average Low Water. Mean of fourteen Spring tides in 1907 and twelve in 1908	81·35
Low-water datum adopted by the Hydrographic survey and correlated with the observations of 1900, as explained	80·80
Lowest level of Low Water in the season of 1900, on September 10	79·35
Lowest Low Water during 6½ months from June to December of 1907, on October 22	79·30
Lowest Low Water in the season of 1908, on September 11	79·40

THE SAGUENAY.—The lower Saguenay from Tadoussac at its mouth to Bagotville in Ha ha bay, forms a deep-water inlet, 55 miles in length, the depth being not less than 100 fathoms throughout. It thus presents the tidal characteristics of deep inlets, such as those in British Columbia; and accordingly the difference in the time of the tide is only 12 minutes on this whole distance of 55 miles, and the increase in the range of the tide is comparatively slight. Chicoutimi is in the river above the head of the inlet; and the tide there is of an estuary type, similar in character to Quebec.

Bagotville.—This is now the terminus of a system of local railways; and it is becoming an important shipping point from pulp mills in the vicinity.

Tidal observations were obtained here in the season of 1915, from June 24 to November 14. A Low-water datum has been established here by the Public Works department; and although it is intended to represent extreme Low Water, it was accepted by this Survey to avoid making a change.

The Public Works Bench-mark is a broad arrow on the east end of a house near the steamboat wharf, on the south side of the road leading to the wharf. This broad arrow is near the north-east corner of the foundation storey, which is built of granite boulders; and as it is cut partly in cement which may scale off, another mark was placed for greater permanence.

Tidal Survey Bench-mark. A brass bolt in east end of house above described, drilled horizontally into the foundation storey at 4½ feet from north-east corner, and 1½ feet from the ground. Elevation of upper side of bolt taken as 100·00 feet.

	Elevation.
Public Works Bench-mark, as described	103·19
Tidal Survey Bench-mark, as described	100·00
Highest High Water in the season of 1915, on November 9	91·95
Average level of High Water at ten Spring tides during the season	90·28
Average level of Low Water at the same ten Spring tides; at 0·82 foot above the Low-water datum	71·58

Low-water datum, defined as 32·43 feet below the Public Works Bench-mark.....
Zero of Public Works scale in 1915, near the South-west corner of the steamboat wharf; set originally at the datum level.....
Lowest Low Water in the season of 1915, on October 10.....

The range of Spring tides at Bagotville at the head of the Saguenay as compared with Tadoussac at its mouth, is shown by the values below. range as in all cases, is the difference in level between average High Wat average Low Water at Spring tides during the season; although in this ins the seasons compared are not the same.

Bagotville.....	Spring range.....	Season of 1915.....	18·
Tadoussac.....	Spring range.....	Season of 1908.....	16·
Tadoussac.....	Spring range.....	Season of 1900.....	15·

The range at Ha ha bay, at the head of the open inlet, is thus only 1 cent greater than at its mouth; as found by comparison with the me these two ranges at Tadoussac, as above given.

Chicoutimi.—As this is in the river, at eight miles above the head o open inlet formed by the lower Saguenay, the range is reduced somewha the river slope, especially during the freshet months. The usual time o freshet in the river is from April to the end of July; and during this pe the High-water level is much the same as usual, but the raised stage of the prevents Low Water from falling to normal. The freshet culminates a the beginning of June; and from that month onward, the level of Low W at successive Spring tides, drops lower till the month of August. The gre range of tide occurs between August and October while the river is low, until the autumn rains begin to raise its level again.

With these varying conditions, the probable minimum range of Sp tides in any season, will be 12 feet when the freshet is at its greatest; and probable maximum 18 feet towards autumn, when the river is at its lowest st

The following summary shows the gradual fall in the height of Low W during the season of 1915 until the autumn rise began. Successive lunar mo are taken, and semi-monthly inequality is thus eliminated as well as diu inequality, to give the true mean height of Low Water above datum.

1915.....	Lunar month, June-July.	Mean Low Water above datum.	3·48
1915.....	Lunar month, July-Aug.	Mean Low Water above datum.	1·61
1915.....	Lunar month, Aug.-Sept.	Mean Low Water above datum.	0·02
1915.....	Lunar month, Sept.-Oct.	Mean Low Water above datum.	0·50
1915.....	Lunar month, Oct.-Nov.	Mean Low Water above datum.	2·14

According to the best information, the lowest tides observed are in F ruary and March, when they may fall to datum; and again at the end of summer, between August and October. The lowest observed, before the c tinuous observations of 1915, were 0·04 below datum in February, 1913, 0·10 below in August, 1914. The highest observed was a November tide wh reached 21·60; and as this was probably a reading on the painted scale, it wo correspond to 21·45 above datum.

D

In the season of 1915, tidal observations were obtained with a registering tide gauge, from June 18 to November 15. The elevation of the zero of the tide scale placed beside the gauge, was ascertained by instrumental levels; and by the usual system of comparisons with this scale, the gauge record was accurately reduced to a uniform datum, correlated with a Bench-mark, according to the method always adopted.

The Public Works Bench-mark is on the river bank, at 250 feet west of the upper side of the steamer wharf. It is the surface of rounded granite rock immediately beside a broad arrow cut flat upon it, and marked by a large "M" chiseled on the rock beside it. The Low-water datum is at 21·30 feet below this Bench-mark.

The top of an iron Ballard post, filled with concrete, at the west end of the wharf and back from the face, is also used as a Bench-mark. It was disturbed by an accident to the wharf; but its present elevation as found in 1915, is given below.

A scale of feet is painted on the concrete face of the wharf beside the steamboat slip. Its zero is presumably at the Low-water datum; but in painting it, a progressive error was made; and at the upper end, 22 feet as painted is at 21·86 above the Low-water datum.

All the tide levels here, are corrected for the discrepancies indicated, and reduced truly to correspond with the Bench-mark on the rock.

	Elevation.
Top of iron Ballard post, as above described; by levels of 1915.....	103·43
True elevation of 22·50 feet on the painted scale on face of wharf....	101·06
Public Works Bench-mark, on granite rock, as described. Elevation adopted.....	100·00
Extreme level said to have been reached by High Water of a November tide; year not known.....	100·15
Highest High Water in the season of 1915, at perigee Springs on November 9.....	98·60
Average level of High Water at ten Spring tides during the season of 1915.....	96·95
(For the levels of Low Water during the season, see statement above given.)	
Low-water datum of the Public Works department, at 21·30 below the Bench-mark.....	78·70
Lowest level of Low Water in the season of 1914. (In August 0·10 below datum, and in October 0·04 below).....	78·60
Lowest level of Low Water in the season of 1915, on September 11....	78·45
Bottom of dredged channel to wharf, at 16 feet below datum.....	62·70

Trois Pistoles.—Tidal observations were obtained here in 1908 and 1909, with a registering tide gauge supplied to the Hydrographic survey. There was not depth enough at the gauge to record low water at Spring tides however; so that some of the levels can only be obtained approximately.

The Bench-mark is a straight line cut on a prominent point of rock, forming part of a reef on the foreshore, at 40 feet from the west side of the wharf. A mark at the same level, was cut on the west side of the wharf, and inscribed "XVI. 54" which was the reading of the wharf scale at the level of the Bench-

mark. This is not connected with the Geodetic levels, as the Bench could not be found, and may be destroyed.

A Low-water datum was adopted by the Hydrographic survey, whic correlated with the datum at Tadoussac and at Father Point by simulta readings at Low Water. The datum was the level reached by the two S tides of August 13 and September 10, 1913, which were at the same lev Trois Pistoles. At Tadoussac, their mean level was 0·23 foot below d there, and at Father Point 0·88 foot above datum. The low-water d as thus adopted, is at 16·77 feet below the Bench-mar the tide referred to the datum are as follows:—

Bench-mark as cut on the rock, and mark on wharf, which define the Low-water datum	
Average level of High Water at nine Spring tides, from June to October in 1909	1
Average Low Water at Spring tides, from tide curves completed when cut off at Low Water (approximate)	
Low-water datum, determined as explained from the Low Waters observed simultaneously	

Escoumains.—Tidal observations were obtained here, with a registe tide gauge supplied to the Hydrographic survey, during a month in the aut of 1910 and they were continued in the season of 1911 from June 13 August 14.

The Bench-mark is a broad arrow cut on the east face of a flat red r situated 94 feet west of the inner end of the wharf.

From this tidal record, a Low-water datum was determined by this Su to correspond with the datum elsewhere, and to give the rise of the tide relativ This datum is at 1·15 feet below average Low Water at Spring tides, or 12 feet below the Bench-mark. The tide levels in relation to this datum ar follows:—

Average level of High Water at four Spring tides in June and July, 1911	15
Bench-mark as above described	12
Average level of Low Water at the same four Spring tides	1
Low-water datum as adopted	0

Jeremy islets.—This locality was preferred to Bersimis for tidal obser tions, as it is on the open, and not obstructed by a bar, as at Bersimis riv Tidal observations were obtained here, with a registering tide gauge suppl to the Hydrographic survey, in the seasons of 1913 and 1914. A tide sc was set with its zero at the Low-water datum adopted by the Hydrograp survey, and the levels are definite in 1913; but in 1914 the comparisons tak were unreliable for both time and height, so that the registering gauge was correlated with the tide scale; and all that could be obtained from the reco was the range of the tide by difference of level. The basis of the tide levels given below, is therefore explained carefully.

The Bench-mark is a broad arrow cut in the rock on the north-east extremity of the small island forming the western entrance point to Jeremy Bay. The Low-water datum adopted by the Hydrographic survey is at 14·71 feet below this Bench-mark. The tide levels in relation to this datum are as follows:—

	Feet
Highest High Water, in the season of 1913, on October 2	16·50
Bench-mark as above described	14·71
Average level of High Water at six Spring tides in the season of 1913, from July to October	14·64
The mean Spring range at five Springs in 1914 is 13·13 feet. Assuming this range to be above average Low Water at Spring tides as determined in 1913, the average Spring rise above datum in 1914 is	14·19
Average for Low Water at Spring tides, from the best levels for Low Water at the six Spring tides in the season of 1913	1·06
Low-water datum, as above defined	0·00
Lowest Low Water in the season of 1913, on August 4. (Below datum)	−0·50

FATHER POINT.—In the early days of the Tidal Survey, the endeavour was made to compute the tide at Father Point from Quebec to avoid multiplying the principal stations. But the relation was complex, involving a double series of variable differences for the time of the tide, and the result was not satisfactory. It was therefore decided to make this into a principal tidal station for the St. Lawrence; and this decision has been fully justified, as it has proved possible to refer a very extended region to it, as explained in the Tide Tables.

Tidal observations were begun at Father Point in December 1894, by means of a registering gauge installed to operate continuously, summer and winter, and working by siphoning. Careful comparisons with open water were taken, to enable an allowance in height to be made near Low Water. Owing to delay in the construction of a wharf at Father Point, the siphoning gauge was kept in operation longer than intended; and the later years were not accepted as reliable in the determination of Mean Sea level. The first complete year's record was lost at sea, in the endeavour to communicate the information to the Admiralty. The years available for the determination are therefore, from the siphoning gauge, 1897 to 1901; and from the open-water gauge when reconstructed at the wharf, October 1904 to date.

The original Bench-mark established in 1895 was the head of a copper bolt let into solid rock near High Water in the vicinity of the gauge. Its elevation was taken as 100·00 feet, and as it has since been covered by the gravel of the new road past the lighthouse, though it is still extant, the Bench-mark on the old lighthouse building has since been used for working purposes. These two Bench-marks are within 50 feet of each other, and their levels have been accurately connected.

In the following list, the extreme levels for 1900 are included, for comparison with the other tide stations in the simultaneous series of that season.

Bench-mark on the old Lighthouse building; a chisel line on a copper plug drilled horizontally into the stone foundation on the east side, at 3½ feet from north-east corner, and marked "C—B.M.—R"

Bench-mark, as above described .....

Original Tidal Survey Bench-mark of 1895, now covered as explained..

Exceptional High Water; the highest recorded while the siphoning gauge was in operation, in 1895 on December 31.....

Highest High Water recorded on the present open-water gauge during the years 1904 to 1916; at 17·90 feet above datum, in 1914 on November 20.. .....

Highest High Water in the season of 1900, during the gale of September 12.....

Highest level of High Water, undisturbed by storms, during the season of 1900.....

Average level of High Water at Spring tides; 14·04 feet above datum in the season of 1900, and 14·67 feet in the season of 1908. Mean elevation resulting.....

Mean Sea level, as determined from the hourly ordinates of the tide during ten complete years of observation, between 1897 and 1911; at 7·560 feet above Low-water datum. (See details given below)..

Low-water datum, as established in 1897 for the siphoning gauge, and transferred at the same elevation in 1904 to the open-water gauge; and maintained with accurate compensation for subsequent settlement of the new wharf.....

(This datum is adopted by the Hydrographic survey for the chart of this region.)

Level termed "Ordinary Low Water" by the Public Works department; defined as 25·50 feet below a mark cut on the wood-work of the old Lighthouse and found in 1897 to be at elevation 104·50.....

Lowest Low Water in the season of 1900, on September 10.....

Extreme Low Water of 1895, April 11; said to be the lowest in 19 years previously.....

Extreme Low Water recorded on the present open-water gauge during the years 1904 to 1916; at 1·75 feet below datum, in 1905, on February 21.....

Mean Sea level at Father Point.—Above the Low-water datum establish the Tidal Survey; as determined from the hourly ordinates of the tide, a series of complete years of observation, as follows:—

One year, from January 1897 to January 1898.....
" " January 1898 to January 1899.....
" " February 1899 to February 1900.....
" " March 1900 to March 1901.....

(The two years 1901 to 1903 were not accepted for Mean Sea level, because the siphoning gauge was not always working satisfactorily. Open-water gauge follows; datum being maintained at same elevation.)

One year, from October 1904 to October 1905.....
" " October 1905 to October 1906.....
" " October 1906 to October 1907.....

One year, from November 1907 to November 1908	7·481
" " June 1909 to June 1910	7·734
" " July 1910 to July 1911	7·588
For ten years. General average adopted	7·560

As the Low-water datum is at 78·95, the elevation of Mean Sea level which results is 86·51 as already stated; and the Bench-mark on the old lighthouse building is found to be 17·16 feet above Mean Sea level, as now determined by these ten complete years of tidal observation here. The elevation of this Bench-mark according to the levels of the Geodetic survey, is 17·18 feet; which differs only by 0·02 foot from this value; which is negligible in view of the actual variation in Mean Sea level from year to year, as above indicated. The Geodetic levels may thus be considered as starting accurately from Father Point in both directions along the south shore of the St. Lawrence estuary.

The determination of Mean Sea level obtained here, has also proved invaluable in enabling the line of levels from Halifax to Father Point, running across the three provinces of Nova Scotia, New Brunswick and eastern Quebec, to be checked at both ends by sea level. From this north and south line as a base, the mean level of the sea has been carried westward along the St. Lawrence, to connect with the New York system at the head of Lake Champlain and in the region of the Great Lakes.

Matane.—Tidal observations were taken here by the Public Works department during five months in 1910, from May to October; the first two months from May 26 to July 25 being obtained with a registering tide gauge supplied to that department. No Bench-mark was established; and the level of Low Water used for working purposes by the Public Works department was one foot too low, relatively to other localities in this region. A Low-water datum was therefore adopted by this Survey at 1·08 feet below the average level of Low Water at Spring tides. The tide levels referred to this datum, including the reductions made by the Public Works department in the later months, are as follows:—

	Feet.
Highest level of High Water during the five months of 1910, on June 8. (This high level was also recorded in 1910 at Grands Méchins)	13·80
Average level of High Water at ten Spring tides observed during the season	12·72
Average level of Low Water at the same ten Spring tides	1·08
Lowest level of Low Water during the five months of 1910, on September 19	0·11
Low-water datum as adopted	0·00

Grands Méchins.—Tidal observations were obtained here in co-operation with the Public Works department for five months in 1910; but better results were deduced from the later series in 1915 and 1916, obtained with a registering tide gauge supplied to the Hydrographic survey. These observations made up four months in all, from July 30 to September 25 in 1915, and in 1916 from May 14 to June 30 and August 2 to October 14.

The tide levels in all three years are referred to the Geodetic Bench M.CCC.XCIX, a chisel line on the end of a copper plug driven horizontally i rock the beach, 5½ feet from the west side of Méchins wharf, at 321 f its er end. The elevation of this Bench-mark above Mean Sea l ained by the Geodetic survey, is 7·81 feet.

Bench-mark M.CCC.XCIX. Elevation adopted. .....
Highest level of High Water, 13·10 above datum, in 1916 on June 18, at perigee Springs. (The tide reached this level also during the Public Works observations in 1910 on June 8) .....
Average level of High Water at eleven Spring tides in 1915 and 1916. (Of these, one is at the moon's mean distance, and the remaining eight are well balanced in pairs in relation to Perigee and Apogee, giving a true average) .....
Low-water datum adopted by the Hydrographic survey, at 6 00 feet below Mean Sea level, taken as the half range of the tide .....
Lowest level of Low Water in the observations of 1910, on October 20..
Lowest Low Water recorded in 1915 and 1916; occurred September 12, 1915 .....

Point des Monts.—This is properly the dividing point between the St rence estuary and the Gulf. Observations were obtained here with a regi tide gauge supplied to the Hydrographic survey, in the seasons of 191 1916; but in the first season the comparisons which define the setting registering gauge with relation to the tide scale, were too deficient to accurate levels to be deduced. In 1916, the gauge was placed at Ans Morue, a bay a mile east of Point des Monts, where a good series of observ was obtained for three months between June 9 and October 6, though m August is wanting.

The Bench-mark is a broad arrow cut in the rock where highest, at à la Morue, at two feet north of cross in front of the fishing camp there. Low-water datum adopted by the Hydrographic survey is at 18·45 feet this Bench-mark.

To compare this datum with those used on the south shore, a val Mean Sea level was obtained from the hourly ordinates on the tide r during one month. The datum was thus found to correspond well with G Méchins. The tide levels in relation to this datum, are as follows:—

Bench-mark as above described .....
Highest High Water recorded in 1916, on July 15 .....
Average level of High Water, from seven Spring tides in the season of 1916 .....
Average level of Low Water at the same seven Spring tides .....
(Of these seven tides, one is at the moon's mean distance, and the remaining six are well balanced in pairs in relation to Perigee and Apogee, giving a true average.)
Low-water datum, as defined .....
Lowest Low Water during the season of 1916, on September 12 .....

Cape Chat.—This is one of the eight tidal stations at which simultaneous observations were obtained in 1900, from July 17 to October 1. The registering gauge was at the wharf in the mouth of Cape Chat river, which is surrounded by bars that begin to show at low tide. The water at the wharf does not therefore fall to its true level at low tide. The difference between the level at the gauge and the open water was found from comparative observations, from which a series of corrections was deduced for the lower levels of the tide as recorded on the gauge. These corrections apply to the last three feet at Low Water, and the maximum at the lowest is nine inches. As there is no Bench-mark here, the tide levels are reduced to the Low-water datum determined from the observations.

	Feet
Exceptional High Water in the season of 1900, during the gale of September 12	13·45
Highest High Water undisturbed by storms in 1900, on August 11	12·76
Average level of High Water, from five Spring tides in the season of 1900	11·80
Average level of Low Water at the same five Spring tides. (Although these Springs are five in number, a true average is obtained by making allowance for the variation between Perigee and Apogee.)	1·00
Low-water datum adopted, at 1·00 foot below Average Low Water, in accord with the datum in this vicinity	0·00
Lowest Low Water in the season of 1900, on September 10. Approximate level	−0·20

Ste. Anne des Monts.—Tidal observations were obtained here with a registering tide gauge supplied to the Public Works department in 1910, from July 30 to September 26.

The tide levels are referred to the Geodetic Bench-mark M.CCC.LXXXIX, a chisel line on the end of a copper plug driven horizontally into the stone foundation on west side of entrance to H. Saceville's residence, on south side of road, Ste. Anne des Monts village. Elevation above Mean Sea level, 19·18 feet.

	Elevation.
Elevation adopted for this Bench-mark	100·00
Highest level of High Water during the two months observation in 1910, on August 22	86·85
Average level of High Water at four Spring tides in the two months	86·40
Average level of Low Water at the same four Spring tides	76·30
Lowest level of Low Water during the two months in 1910, on September 20	75·70
Low-water datum adopted, at 0·90 foot below Average Low Water, to correspond with the datum elsewhere	75·40

ST. LAWRENCE ESTUARY.—LOW WATER DATUM AND RISE OF TIDE

Average Low Water is average level of the lowest Low Water at each tide. Influence of moon's distance may cause difference of 2 or 3 feet b the two Springs of the month. These are carefully balanced to obtain true a Low Water. The rise at Neap tides where determined, serves to indicate r of Neaps to Springs.

Locality.	Description of Datum.	Datum below Average L. W. at Spring tides.		Spring Rise above L.W. datum.	Nea a L.W.
		Year.	Feet.	Feet.	F
Quebec	Admiralty chart datum	In 1900.	1·09	18·21	
Quebec	" "	In 1908.	1·19	18·53	
Grosse Isle	" "	In 1900.	0·95	19·75	
Crane island wharf	Ship Channel survey datum at 0·26 below Admiralty datum at L'Islet	In 1908.	0·26	19·24	
L'Islet	" " "	In 1900.	0·76	18·36	
L'Islet	" " "	In 1908.	0·25	18·43	
Orignaux Point	Admiralty chart datum	In 1900.	0·18	18·34	
Cap à l'Aigle	Hydrographic Survey datum	In 1905.	0·50	17·45	
Rivière du Loup	Low-water datum at 25 feet below Admiralty benchmark	In 1900.	0·65	16·37	
Tadoussac	Hydrographic Surv. datum	In 1900.	0·55	16·27	
Tadoussac	" "	In 1908.	0·58	16·91	
Trois Pistoles	" "	(Approx.)	1·20	15·82	
Escoumains	" "	In 1911.	1·15	15·35	
Jeremy islets	" "	1913–14.	1·06	14·42	
Father Point	Tidal Survey datum	In 1900.	1·34	14·04	
Father Point	" "	In 1908.	1·43	14·67	
Matane	Tidal Survey datum	In 1910.	1·08	12·72	
Grands Méchins	Hydrographic Surv. datum	1915–16	0·95	11·95	5 to
Point des Monts	" "	In 1916.	0·98	11·92	5 to
Cape Chat	Tidal Survey datum	In 1900.	1·00	11·80	
St. Anne des Monts	" "	In 1910.	0·90	11·00	

ST. LAWRENCE ESTUARY.—VARIATIONS IN THE TIDE.

The table here given shows the variations in the tide with the moon's distance, when Perigee and Apogee fall at the Springs; based on the actually simultaneous observations throughout the estuary in 1900. The Neaps are also given where they have been determined. Such a comparison must be based on the range of the tide, which is the true amplitude of the tidal undulation, independent of any datum level. The mean Spring range given, is the average as found for the whole season.

Locality.	Date, 1900.	Height above Datum.		Spring Range.		Difference.	Mean Range.	
		H. W.	L. W.	Perigee.	Apogee.		Springs.	Neaps.
		Feet.	Feet.	Feet.	Feet.	Feet.	Feet.	Feet.
Quebec.....	Aug. 25..	16·80	1·10	.....	15·70			
						2·45		
	Sept. 10..	18·00	−0·15	18·15	.....			
						2·95		
	Sept. 24..	16·20	1·00	.....	15·20			
						3·60		
	Oct. 10..	19·80	1·00	18·80	.....			
						3·40		
	Oct. 24..	16·50	0·70	.....	15·80			
				Mean...	.....	3·00	17·12	11·12
Grosse Isle.....	Aug. 25..	18·25	1·15	.....	17·10			
						3·30		
	Sept. 11..	20·45	0·05	20·40	.....			
						3·30		
	Sept. 23..	18·05	0·95	.....	17·10			
						3·55		
	Oct. 10..	21·30	0·65	20·65	.....			
				Mean...	.....	3·38	18·80	
L'Islet.....	Aug. 25..	17·10	1·50	.....	15·60			
						3·55		
	Sept. 11..	19·00	−0·15	19·15	.....			
						3·50		
	Sept. 25..	17·00	1·35	.....	15·65			
						3·75		
	Oct. 10..	19·65	0·25	19·40	.....			
				Mean...	.....	3·60	17·60	10·12
Orignaux Pt.....	Aug. 25..	17·25	1·90	.....	15·35			
						5·65		
	Sept. 10..	18·85	−2·15	21·00	.....			
				Mean...	.....	5·65	18·16	
Riv. du Loup....	Aug. 25..	15·45	2·30	.....	13·15			
						5·60		
	Sept. 11	17·45	−1·30	18·75	.....			
						5·70		
	Sept. 25..	15·30	2·25	.....	13·05			
						5·90		
	Oct. 10..	17·75	−1·20	18·95	.....			
				Mean...	.....	5·73	15·72	

ST. LAWRENCE ESTUARY.—VARIATIONS IN THE TIDE.—*Concluded.*

Locality.	Date, 1910.	Height above Datum.		Spring Range.		Difference.	Mean
		H. W.	L. W.	Perigee.	Apogee.		Springs.
		Feet.	Feet.	Feet.	Feet.	Feet.	Feet.
Father Point	Aug. 25	12·90	2·10	.....	10·50		
	Sept. 11	14·65	−0·30	14·95	.....	4·15	
	Sept. 27	12·60	2·20	.....	10·40	4·55	
	Oct. 10	11·95	−0·35	15·30	.....	4·90	
				Mean	.....	4·63	12·70
Cape Chat	Aug. 11	4·75	1·10	10·65	.....		
	Aug. 25	10·40	2·75	.....	7·65	3·00	
	Sept. 10	11·35	0·60	10·75	.....	3·10	
	Sept. 25	9·70	2·50	.....	7·20	3·55	
				Mean	.....	3·22	10·80

NOTE.—In the series of ranges, the decrease from Orignaux Point to L'Islet must be a as actual; as the same result is obtained from the part of the season at the two places was simultaneous. It is probably due to the division of the river into two channels Orignaux Point, these channels uniting again at Grosse Isle.

GULF OF ST. LAWRENCE.—NORTH SHORE.

During the season of 1910, simultaneous observations were obtained the North Shore of the Gulf of St. Lawrence, on an extent of 490 by means of a series of registering tide gauges. As far as Harrington, they under the immediate supervision of the Superintendent; and in the vi of Belle Isle strait, they were supervised by Mr. H. W. Jones.

Seven Islands.—The gauge was erected at the village of Seven Islan the east side of the bay. It was placed against an isolated crib, intend form part of a wharf eventually.

The Bench-mark is the top of the concrete foundation of the new cl at the west side of the main entrance. The tide scale at Seven Island set one foot lower than the scale on the wharf at Clark City, on the op side of the bay; the levels being carried across by measurements to the surface taken simultaneously.

	Ele
Bench-mark on the church, as described.....	1
Reference point on top of crib used for setting scale; at 15·25 feet above zero of scale at Clark City wharf, by water transfer.....	1
Highest High Water in the season of 1910, on July 7 and October 21.....	1

Average level of High Water, at eight Spring tides during the season, from July to October	112·92
Average level of Low Water, at the eight Spring tides during the season	103·06
Low-water datum adopted	102·40
Lowest Low Water in the season of 1910, on October 21	101·90
Zero of scale on Clarke City wharf	101·00
Zero of tide scale at Seven Islands, set one foot lower than the scale at that wharf	100·00

Ellis bay.—Near the west end of Anticosti island; and the terminus of the railway built by the Menier company. The datum for this railway is the level of High Water; and as this important datum already existed, the elevation of 100·00 feet was taken for it, to keep the tide levels in harmony with the railway levels. For convenience, the tide scale was set with an even foot (8 feet on the scale) at this High-water datum level. A new Bench-mark was also placed, for the greater security of both sets of levels.

Bench-mark, at the southwest corner of the large warehouse near the head of the wharf; a brass bolt drilled horizontally into the masonry, on the front facing the sea: at one foot from the south end, and nine inches above the ground.

	Elevation.
Bench-mark as above described	106·17
Highest High Water in the season of 1910, on August 6	101·15
Average level of High Water, at seven Spring tides during the season from July to October	100·52
(Although this is not an even number of Spring tides, the value is balanced because there is no semi-monthly inequality in July.)	
High-water level adopted as the datum for the Anticosti Railway	100·00
Average level of Low Water, at the seven Spring tides during the season	93·80
Low-water datum adopted	93·30
Lowest Low Waters during the observations of 1910, on September 19 and October 2	93·00
Lowest Low Water in May and June, from comparison with the record of a Pressure gauge placed at the wharf by the Menier company	92·95
Zero of tide scale, set as explained	92·00

Mingan.—The registering gauge was placed at the end of a boat wharf built with trestles which are removed in winter. The wharf barely reached to Low Water and on August 16 it was extended and the gauge moved far enough out to record all low waters.

No permanent Bench-mark was placed here, as the country is sandy and there are no masonry buildings. The elevation 100·00 feet was adopted as extreme High Water; and 8 feet on the tide scale corresponded with this. On August 16 the scale when moved out, was set exactly two feet lower to maintain the continuity of the levels; and 10 feet on the scale thus corresponded with elevation 100·00. This change is allowed for in the reductions.

	Eleva
Highest High Water in the season of 1910, on July 4	100
Next highest on October 21	99
Average level of High Water, at eight Spring tides during the season, from July to October	99
Average level of Low Water, at the eight Spring tides during the season	91
Low-water datum adopted	91
Lowest Low Water in the season of 1910, on October 20	91

Eskimo Point.—There is a well-built wharf here, at which the gauge placed. The Bench-mark used for reference in the tide levels, is a six i spike driven horizontally into a wharf post, on the east side of the wharf, 27 feet from the shore end. The wharf is here $3\frac{1}{2}$ feet above the slope of the bea and the spike is marked with a broad arrow cut on the timber.

	Eleva
Cap of wharf, above the Bench-mark	102
Cap of wharf at the site of the gauge	101
Elevation of Bench-mark, as described	100
Exceptional High Waters after the gauge was discontinued, from scale readings taken by the observer; on November 7, 13·00 feet on scale and on December 2, 12·50 feet. Elevation, November 7	98·
Highest High Waters recorded by the tide gauge during the observations from July to October, 1910, on July 8 and October 20	97·
Average level of High Water, at eight Spring tides during the season	96·
Average level of Low Water at the eight Spring tides during the season	90·
Low-water datum adopted	90·
Lowest Low Water in the season of 1910, on September 19	90·
Next lowest, on October 20; for comparison with the Low Water of this date at other localities	90·

Natashkwan harbour.—The Bench-mark is the top of a heavy eye for ring bolt (but without the ring) let into the granite rock on the north side the wharf. From the north-west corner of the crib on which the main shed built, the measurements to this eye bolt are as follows:— 20 feet 6 inches nor and 3 feet 6 inches east.

	Elevati
Exceptional High Water after the gauge was discontinued, from scale readings taken by the observer; on November 17, 8·60 on scale	100·(
Highest High Water recorded by the tide gauge during the observations from July to October, 1910; on October 20	100·(
Elevation of Bench-mark, as described	100·(
Average level of High Water at eight Spring tides during the season	99·4
Average level of Low Water at the eight Spring tides during the season	93·8
Low-water datum adopted	93·5
Lowest Low Water in the season of 1910, on July 6	93·4
Next lowest, on October 22	93·6

Harrington.—The Bench-mark is the top of a brass bolt in the rock, bein the "Boundary mark" at corner of lots 8 and 10 on land plan by C. E. Lemoine dated at Quebec, 19 November, 1907.

	Elevation.
Bench-mark, as described	100·00
Exceptional High Water of 1908, February 2, during a southeast gale and snow storm; height reached by this tide, from the mean elevation of two points marked at the time	95·75
Highest High Water in the season of 1910, on October 20	93·45
Average level of High Water, at six Spring tides during the season, from August to October	92·63
Average level of Low Water, at the six Spring tides during the season	86·46
Low-water datum adopted	86·10
Lowest Low Water in the season of 1910; on October 22	86·05

Bonne Espérance.—The observations here extended only from the middle of July to the beginning of September; so that the extreme tides of October were not obtained.

The Bench-mark is the top of a brass bolt set vertically into granite rock, at the southern extremity of Bonne Espérance island; and about six feet above extreme High Water.

	Elevation.
Bench-mark, as described	100·00
Highest High Water observed during the observations of 1910, on August 5	93·45
Average level of High Water, at four Spring tides during the season of observation	93·20
Average level of Low Water, at the four Spring tides during the season	87·27
Low-water datum adopted	87·00
Lowest Low Water observed during the observations of 1910, on August 20	87·00

Port Saunders.—On the Newfoundland side, in Hawke bay. The Bench-mark is a brass bolt set vertically into the limestone rock, at a foot above extreme High Water. From the Bench-mark, the bearings of the two hill tops near by, are N.E. ½ E. and N.W. by W. (magnetic) and the shoal at the head of the bay bears S.E.

	Elevation.
Bench-mark, as described	100·00
Highest High Water in the season of 1910, on October 20	99·80
Average level of High Water, at eight Spring tides during the season, from July to October	98·90
Average level of Low Water, at the eight Spring tides during the season	92·79
Low-water datum adopted	92·50
Lowest Low Water in the season of 1910, on October 21	92·25

Summary for the North shore, Gulf of St. Lawrence.—In the table below, the extreme difference of level is from the lowest observed to the highest at different dates during the season, but omitting exceptional tides not in the period of simultaneous observations or in other years. The rise of Spring tides is from the Low-water datum to average High Water at Springs. The datum as adopted along this shore is from 0·27 to 0·66 foot below average Low Water

at Springs, as will be seen in the elevations given; this margin being in pro portion to the total range of the tide.

Locality.	Extreme difference of level.	Rise of Spring Tides.
	Feet.	Feet.
Seven Islands village	11·70	10·7
Ellis Bay, Anticosti	8·15	7·2
Mingan	8·85	7·6
Eskimo Point	7·55	6·8
Natashkwan	7·15	5·9
Harrington	·40	6·5
Bonne Esperance*	6·45	6·2
Port Saunders, Newfoundland	7·55	6·4

* Values not truly comparative with other localities, as season was shorter here, and greatest range in October was not obtained.

Forteau bay, Belle Isle strait.

This tidal station commands the northern entrance by which the tides enter the Gulf of St. Lawrence from the Atlantic. As regards the Gulf area in general, the tidal undulation which enters here has a very limited effect as compared with the main entrance at Cabot strait; as Belle Isle strait has only a width of 11 miles and a depth of 30 fathoms, whereas Cabot strait is 67 miles wide and 250 fathoms deep. There is, however, a considerable region, comprising the strait itself and some portion of the north-eastern arm of the Gulf, for which Forteau bay may serve as a reference station. It also supplied the tidal data for the strong tidal streams of the strait, during their investigation in 1894 and 1906.

A thoroughly equipped tide gauge was erected in 1894 on the west side of the bay. The tide house was placed on a block of crib-work built at the end of a fishing stage which afforded an approach to it from the shore. A permanent Bench-mark was established for the tide levels, and a dipleidoscope or meridian instrument was erected to obtain time from the sun. The essentials of time and height for the tidal observations were thus provided for.

This crib-work protected the iron cylinder of the gauge, three feet in diameter, set vertically within it, which encased the tide pipes. As it rested on rock, it was thought safe to take measurements for the levels from points on the ironwork. But the structure was shifted horizontally on the rock by the heavy ice in winter. There was thus much difficulty in maintaining accurate levels in the early years, especially in so remote a locality. The ironwork was found to have risen in elevation, and the zero of the tide scale to be lowered, apparently by a slight canting of the crib-work. The vertical displacement resulting, ranged from one to four inches. For greater stability, in September 1898, additional crib-work was built on two sides of the original block, and faced with heavy hardwood planking; and since then any vertical displacement or settlement has not been more than 2 or 3 inches in half a dozen years. All changes of more than 0·01 foot since that date, have been allowed for in the reductions, as at all the principal tidal stations. The years on which Mean Sea level is

based, are accordingly from 1898 onward. In the last four years, from 1913 to 1917, the settlement has been only 0·04 foot, which can readily be allowed for in the reductions.

The original Bench-mark, to which the elevation 100·00 feet was given, is the plate on top of the iron pillar of the dipleidoscope. Although this pillar was set well into the ground and surrounded by a large iron drum filled with concrete, it was raised by the frost from elevation 100·00 to 100·07 in five years, and in subsequent years it settled again to 100·03. The reduction of the early levels is therefore brought finally to accord with the Bench-mark established in 1900; namely, a bronze bolt drilled into a small reef of solid rock at about half tide, found in the vicinity of the gauge. An improved type of sight gauge or floating scale was also devised, to obviate any change of length through accident. The open tide scale, attached to the crib-work, could only be used in the summer time for reference and checking.

The Tidal Survey Bench-mark is the upper side of a bronze bolt set horizontally into the edge of a small reef of rock, at 78 feet due south from the south-east corner of the crib-work of the tide gauge.

It was found in 1905 that a Bench-mark had been placed on the west side of Forteau bay by Captain W. F. Maxwell, R.N., in 1890, during the surveys for the revised chart of Belle Isle strait. It is a broad arrow cut on a vertical face of red granite rock, facing the west, in the vicinity of the High-water mark; at 410 paces north-eastward from the tide gauge. The Admiralty Low-water datum is defined as 8·00 feet below this Bench-mark. The Tidal Survey datum is in close agreement with this.

	Elevation.
Surface of plate on pillar of dipleidoscope; originally taken as 100·00. Elevation in June, 1917	100·03
Floor of tide house, on the crib-work	92·21
Admiralty Bench-mark, as described	88·97
Tidal Survey Bench-mark, the upper side of horizontal bolt in reef, as described	84·09
Mean Sea level, as determined from the hourly ordinates of the tide during five complete years, from 1898 to 1904	83·79
Low-water datum, to which the tidal record from 1898 to 1917 is accurately reduced	81·00
(The Admiralty Low-water datum is practically the same; as 8 feet below the Admiralty Bench-mark makes its elevation 80·97).	
Exceptional Low Water, on August 2, 1894	80·37

The values of Mean Sea level in the successive years are given below, as heights above the Low-water datum at elevation 81·00:—

	Feet.
One year, from October 1898 to October 1899	2·662
" October 1899 to October 1900	2·761
" October 1900 to October 1901	2·860
" September 1902 to September 1903	2·873
" September 1903 to September 1904	2·815
Mean height above Low-water datum	2·794

Chateau bay.—At the eastern end of Belle Isle strait. A tide gauge placed in 1899 at Henley harbour, which opens off this bay, to obtain the of the open Atlantic at the eastern end of Belle Isle strait. The observa were primarily intended for time comparisons with Forteau bay, to deter the difference in the time of High and Low Water on a run of 60 miles from end of the strait to the other; and for time correlations with other prin stations. The observations were from July 24 to October 13.

There was no Bench-mark established here; but only a mark on the at the level of 4 feet on the tide scale, to insure its not being displaced in he The tidal record obtained will afford the rise at Spring and Neap tides a average Low Water, or any other data that may be desired, if further inve ations are made in this region.

Chaleur Bay.

Early tidal observations were obtained in 1896 at Carleton Point, which selected as being as near the head of the bay as possible, while beyond the i ence of the Restigouche river. The similarity of the tide in this bay an the St. Lawrence estuary was thus ascertained. In 1913 simultaneous ob vations were obtained at Port Daniel and Paspebiac; and in 1914, at Bath and Caraquet. In 1917, observations are in progress at Shippegan and Mi and north of the bay, at Point Peter and Gaspé.

Port Daniel.—The Bench-mark is the top of a brass bolt set vertically the rock which is at the level of the road as it approaches the wharf. The is 21 feet east of the timber wall along the edge of the rock, and about 35 from extreme High Water, measured horizontally from the beach below. elevation of this Bench-mark in the Geodetic levels of 1915, is 16·48 feet.

	Elev
Bench-mark, as above described	10
Highest High Water in the season of 1913, on October 30	8
Average level of High Water, at eight Spring tides during the season, from July to October	8
Approximate Mean Sea level, determined from two lunar months as 2·50 and 2·37 feet respectively, above the Low-water datum. Mean, 2·43 feet	8
Average level of Low Water, at the eight Spring tides during the season.	8
Low-water datum adopted	8
Lowest Low Water in the season of 1913, on October 28	7
Next lowest, on November 1, for comparison with the simultaneous tide at Paspebiac	7

Paspebiac.—A Bench-mark was found to exist here, which was utilize the hope of correlating any previous data with the present tide levels; altho no information could be obtained regarding it. It is a bolt with a sharp e set horizontally into the front wall of the Powder House, and marked wi broad arrow cut above it on the stonework and pointing downwards. bolt is in the front of the house facing southwest, at 4 inches from the v corner, and two feet above the ground.

The Powder House is a small building of red and grey sandstone, 12 feet by 14 feet, situated on the Paspebiac beach, midway between the Government wharf and the wharf of Robin Jones & Whitman, which are about 1,100 feet apart. The elevation of this Bench-mark in the Geodetic levels of 1915, is 9·79 feet.

	Elevation.
Bench-mark, as above described	100·00
Highest High Water in the season of 1913, on October 30	94·15
Average level of High Water, at eight Spring tides during the season, from July to October	93·34
Average level of Low Water, at the eight Spring tides during the season	86·97
Low-water datum adopted	86·87
Lowest Low Water in the season of 1913, on November 1	86·20
Low Water of October 28	86·55

It will be noted that the Low-water datum here and at Port Daniel, is practically at the average level of Low Water during the season. It is so taken to correspond with the datums at Bathurst and Caraquet on the other side of the bay, which were found to be at this average level.

Carleton Point, Que.—The reference marks for levels in the observations of 1896, were the top of a pile beside the tide scale which has since been cut shorter; and the upper side of a bolt fastening a window shutter on south end of freight shed at head of wharf, marked with a broad arrow. This bolt is also gone, but the hole is available for reference. Its elevation in the Geodetic levels of 1915, is 12·72 feet.

For greater security, the elevation of three ring bolts in the cap of the wharf were obtained in 1911, as given below.

	Elevation.
Reference mark; bolt of shutter of freight shed, as described	99·35
Top of ring bolt. First, in cap of wharf, west side	97·14
" Second, " "	97·11
" Third, " "	97·23
Highest High Water in the season of 1896, on November 6	93·40
Average level of High Water, at nine Spring tides during the season, from July to November	91·91
Average level of Low Water, at the nine Spring tides during the season	84·77
Low-water datum adopted	84·50
Lowest Low Waters in the season of 1896, on October 9 and November 5	83·80

Dalhousie.—No observations have yet been taken here or at Campbellton by the Tidal Survey, as Carleton Point was accepted as the head of Chaleur bay for purposes of tidal comparison, as explained.

Some general levels for the tide, and Bench-marks, have been established by the Public Works department however; and it is their practice to adopt elevation 100·00 feet for High Water, at all the ports on the coast of New Brunswick. This elevation is therefore retained in these levels, wherever it has been definitely established.

The Public Works Bench mark at Dalhousie is a broad arrow cut th
top of a pointed rock, near the shore end of the Government wharf, n
foot from its west side. It is covered at High Water.

There is also a Geodetic Bench-mark on the south side of the small
island, which extends eastward from the approach to the Government
behind its head. It is a copper plug set into the face of the rock at 110
from the east side of the approach and marked C.—B.M.—CC LXXXIV.
tide levels of the Public Works department, and of the Geodetic surve
as follows:—

Description.	P. W. Depart.	Geo Sur
	Feet.	Fe
Geodetic Bench-mark as described		
Highest High Water in Public Works observations, in the seasons of 1915 and 1916	101·35	
High Water ordinary Spring tides	100·00	
Original Public Works Bench-mark, near shore end of wharf on west side	99·42	
Lowest Low Water in Public Works observations, in the seasons of 1915 and 1916	91·05	
Low Water ordinary Spring tides: the datum of the Public Works department	90·00	

Campbellton.—The elevation of 100·00 which was first adopted for
Water, was found to be too low, and it was raised to 101·00; making the
Spring range, 10 feet.

The Bench-mark is the head of the highest spike in a cluster of four, dr
into the top of a face pile where the cap is notched, on the north face of
Railway wharf; at 28 feet from the east end of the freight shed, and 4½
east of an angle in the face of the wharf. The tide levels are as follows:—

Description.	P. W. Depart.	Geod Surv
	Feet.	Fee
Bench-mark, as above described	104·29	+
Exceptional High Water	102·00	
Usual High Water at Spring tides	101·00	+
Usual Low Water at Spring tides	91·00	
Low water datum	90·00	—

The datum at Dalhousie is in fair accord with this; as the small differe
of 0·20 foot in actual elevation, may be taken to represent the river slope betw
the two places.

The datum for the dredging of the bars in the river below Campbellto
defined as 14·29 feet below the Bench-mark; and it thus coincides with the L

water datum as above stated. The dredging is to a depth of 19 feet below this datum, and the bottom of the dredged channel is thus at elevation 71·00 feet.

Restigouche river.—Although the tide has a range of eleven feet at Campbellton, it only extends as far as Moffat, about five miles above Campbellton, owing to the slope of the river and the rapids in it.

Bathurst.—Tidal observations were obtained here in the season of 1914, and at that date there was already a Bench-mark established by the Geodetic survey, and a Low-water datum established by the Public Works department for the dredging at the entrance to the harbour. Care was therefore taken to correlate the new observations with these levels.

The Bench-mark is a chisel line on a copper plug in the north front of the Post Office building, near the north-east corner, in the fourth course of masonry above the sidewalk; and marked C.—B.M.—D.CCC.LXX. Its elevation in the Geodetic levels is 22·05 feet.

The Low-water datum is defined on the plan of Bathurst harbour, by Mr. Voligny of the Public Works department, as 24·80 feet below this Bench-mark. It is also at 7·00 feet below ordinary High Water at Spring tides, which is taken as usual as elevation 100·00 in the Public Works levels.

A tide scale was placed by the Public Works department at the Public wharf, which is situated at the middle of the long causeway connecting Bathurst village with the town. The zero of this scale represents the Low-water datum; but it was found in the Tidal Survey levels of 1914, to be 0·08 foot below datum. In the tidal observations, which were taken at Bathurst village, the tide scale was set for convenience at one foot lower than this; and the Low-water datum was thus at 1·08 on the scale. The tide levels when reduced to the same standard, are as follows:—

	Elevation.
Bench-mark D.CCC.LXX. on Post Office building	117·80
Exceptional High Water during a gale on November 20, 1914; reached 11·50 on Public Works scale	104·40
Highest High Water as recorded on the tide gauge in the season of 1914, on October 22	100·70
High Water ordinary Spring tides (P.W. dept.)	100·00
Average level of High Water at nine Spring tides during the season of 1914, from June to October	99·91
Average level of Low Water at the nine Spring tides during the season	93·27
Low-water datum, as above described, and adopted for the dredging operations	93·00
Zero of Public Works scale at the Public wharf, from levels of 1914	92·92
Level taken as Extreme Low Water, at −3·00 in the Geodetic levels	92·75
Lowest Low Water as recorded on the tide gauge in the season of 1914, on July 8	92·70
Bottom of dredged channel, entrance to Bathurst harbour, at 17 feet below datum	76·00

Caraquet.—There is some uncertainty in the levels here, because of the disturbance of the original Bench-mark. A high bank runs along the shore behind the wharf, which is reached by a curved approach; and the original

Bench-mark was a cement pillar at the top of the bank, but it has settled tipped to an angle. The best remaining reference points are the heads of b through the cap of the wharf, and the zeros of two tide scales; but there is s uncertainty in the identification of the bolts used, which are in the long cur approach to the wharf; and there is possibility of the settlement of the s at the head of the wharf. The final values of the levels as here given, are closest that can be arrived at, when checked with the data in the District of of the Public Works department at Chatham. Any outstanding uncertain in the older levels do not however exceed 0·05 or 0·12 of a foot.

In the season of 1913, when observations were taken by the Tidal Surv a new Bench-mark was established, to which the tide levels of that season referred. This Bench-mark is on a rocky point which stands above the st bank behind the beach, at the Government wharf. It is a horizontal groo marked with a broad arrow, cut on the face of this rock. From a point on High-water mark on the shore, which is in line with the straight part of the wh on the east side, it is 1·40 feet westward to the bluff on which the Bench-ma is cut.

	Elevat
Bench-mark on rock, as described	132·
Top of bolt through cap in approach to wharf, used as Public Works Bench-mark	106·
Top of bolt through cap in approach, used as Geodetic Bench-mark; different from the above	106·
General level of flooring of wharf "at the shore end" used for reference in the Geodetic levels. Elevation, Geodetic series, 9·17	105·
Highest High Water in the season of 1913, on July 7	100·
Next highest, on October 30 and 31	100·
High Water ordinary Spring tides. (P.W. department.)	100·
Average level of High Water at eight Spring tides during the season of 1913, from July to October	99·
Low Water ordinary Spring tides, Public Works department; defined as 12·50 feet below the bolt used as a Bench-mark. Adopted as Low-water datum by the Tidal Survey	94·
Average level of Low Water at the eight Spring tides during the season	93·
Lowest Low Water during the season of 1913, from July to October; on October 28	93·
Zero of tide scale placed by Geodetic survey at head of wharf; at 13·46 feet below their Bench-mark	92·
Zero of this scale, as found in 1913	92·
Extreme Low Water of November 1, 1913	92·

The tide at Caraquet is characterized by the unusual feature of a lar diurnal inequality at High Water, whereas Low Water is little affected by The semi-monthly inequality, or difference in the range at perigee and apoge is much less. The season of 1913, afforded a good opportunity to determi these inequalities; as the moon was at its maximum declination at the Sprin in July and at the end of October, and perigee was at the Springs in August a September. A digest of the levels at Spring tides during the season, affor the following results:—

	Feet.
Diurnal inequality in High Water; mean value as determined in July	2·90
Diurnal inequality in Low Water; mean value as determined in July and October	0·48
Spring range with moon at Perigee	5·62
True mean Spring range, during the season	4·67
Spring range with moon at Apogee	4·13

In the ranges, the diurnal inequality is eliminated to give a true comparison. It is to be noted that the diurnal inequality in the High Water level is 62 per cent, or nearly two-thirds, of the mean Spring range; and also that it is nearly double of the semi-monthly inequality. Also, in the tide levels, the averages for High Water and Low Water are the actual averages without distinction of these causes, which occasion them.

Miramichi Bay and Southward.

From a tidal point of view, this region may be taken to include the western end of Northumberland strait, as far as Cape Tormentine. The tide is here characterized by a strongly marked diurnal inequality. In the early investigations, a tide gauge was established in 1896, at Lower Negnac; in the endeavour to obtain the tide on the western side of the Gulf of St. Lawrence, as near to the open as shelter could be obtained.

Lower Negnac.—In the plans for dredging in the Public Works department, the Low-water datum was altered by two feet between 1903 and 1905; and although the original datum may have been high, this large alteration is too much. Also, the rise of 5 feet at Spring tides is more than enough, as 4½ feet corresponds better with the tidal observations.

The Admiralty Low-water datum for Miramichi bay was established at Portage island, near the main entrance through the chain of islands. In these levels, care has been taken to bring the datum elsewhere in the bay into relation with this, with allowance for the difference in the range of the tide. Also, in the Public Works levels, the elevation of High Water is taken as 100·00 feet throughout; and consequently any alteration of the rise affects the Low-water datum only.

The Bench-mark is on the south-east corner of the lighthouse, which stands 400 feet west of the wharf. It is an inverted broad arrow cut on the east face of the corner timber of the lighthouse, at the level of the plank platform around it. The elevation of this Bench-mark is given as approximately 5·30 feet, in the Geodetic levels.

The lighthouse is supported on four main corner posts, which are said to go about two feet into the ground, and to rest on the rock. There is no likelihood of settlement therefore, between 1896 when the tidal observations were taken and 1903 and 1905, the dates of the Public Works levels.

	Elevation.
Bench-mark on lighthouse, as described	102·87
Highest High Water in the season of 1896, on October 1	100·70
High Water ordinary Spring tides, adopted as basis of Public Works levels	100·00

Average level of High Water at seven Spring tides which were undisturbed, during the season of 1896, from July to October	9
Average level of Low Water at eight Spring tides during the season	9
Low-water datum, to correspond with the rise of 4½ feet	9
Lowest Low Water in the season of 1896, on October 10	9

Oak Point.—This locality was selected for tidal observations, to repres the head of Miramichi bay, beyond the influence of the river. From a car correlation of the range of the tide and the Low-water datum, to obtain a consist result, the Public Works datum was made 0·50 foot higher, corresponding t Spring rise of 5½ feet, instead of 6 feet.

The original Bench-mark, a bolt set in the rock by the Tidal Survey 1908, was lost by the undermining of the cliff which fell away. The later Ben marks were correlated with the tide levels by means of the best existing refere marks, such as the zero of a tide scale and the surface of the wharf floori and they may be accepted as practically accurate throughout.

The Public Works Bench-mark is the end of an iron tube set vertica in a concrete block, at the top of the bank, at 85 feet west of the Oak Po wharf.

The Geodetic Bench-mark is a copper bolt set vertically into a large imbed granite boulder, in front of the fish shed on the shore road at the head of t wharf; and marked C.—B.M.—M.CCCC.XXII. Its elevation in the Geodetic lev is 17·77 feet.

	Elevat
Geodetic Bench-mark, as described	114·
Public Works Bench-mark, as described	112·
Wharf flooring, at shore end of wharf	103·
Highest High Water in the season of 1908, on October 30	101·
Next highest, on July 15	100·
High Water ordinary Spring tides (P.W. dept.)	100·
Average level of High Water at ten Spring tides during the season of 1908, from June to October	99·
Average level of Low Water at the ten Spring tides during the season	94·
Low-water datum as adopted	94·
Lowest Low Water in the season of 1908, on October 14	93·
Next lowest, on June 18	93·

Chatham.—The Low-water datum as established here by the Public Wor department, and the rise of 6 feet at Spring tides, are both accepted as in acco with the Tidal Survey observations, during two seasons.

The Public Works Bench-mark is the surface of the stone door sill at t back entrance to the wing of the Post Office building, facing the river; the poi used as a Bench-mark being at its west end.

The Geodetic Bench-mark is a chisel line on a copper plug set horizontal into the masonry of this wing of the Post Office, on its east side, above the secon basement window from the north end. It is marked C.—B.M.—M.CCCC.XI and its elevation in the Geodetic levels is 10·23 feet.

	Elevation.
Public Works Bench-mark, as described	107·14
Geodetic Bench-mark, as described	106·50
Extreme High Water during a gale on November 20, 1914	101·50
Exceptional High Water on December 14, 1914; from reading on tide scale	101·10
High Water ordinary Spring tides (P.W. dept.)	100·00
Low Water ordinary Spring tides (P.W. dept.)	94·00

Miramichi river.—In 1903, observations were taken as readings on a series of tide scales along the Miramichi river, by Mr. G. Stead, District Engineer of Public Works. These observations were taken at Loggieville below Chatham, at Nelson opposite Newcastle, and at Millerton and Cassilis. They have proved valuable as a basis for tidal differences by which the time of the tide is known with reference to the Tide Tables. The zeros of these scales were referred to the level of the cap of the wharves at which they were placed, or to other reference marks.

In the Miramichi, the tide runs up both branches of the river for a distance of 19 miles above Chatham; and it ends at rapids in these branches, at which it still has a rise of two feet.

Point Sapin.—This is at ten miles south of Point Escuminac, at the mouth of Miramichi bay. A breakwater in the form of an L has been built here in recent years, at which the tide gauge was placed. In 1914, simultaneous observations were obtained here, and at Richibucto and Shediac.

The rise of 5 feet at Spring tides, as adopted by the Public Works department, was found to be correct, but the actual elevation of both High and Low Water was higher than it should be. As the Low-water datum at Richibucto proved satisfactory, a series of simultaneous comparisons was made between the two places at all the Spring tides during the season from June to September, by which it was ascertained that the datum at Point Sapin was too high by 1·50 feet. Both High and Low Water required to be lowered by this amount; and on consultation with the District office of Public Works, it was decided to increase the elevation of the Bench-mark by 1·50 feet which would have the desired effect and would also retain the elevation of 100·00 for High Water, and 95·00 for Low Water as before.

The difficulty of determining such levels from a short series of observations, when works of construction are begun, is very considerable on such a coast where the diurnal inequality is so large; but in the Tidal Survey observations, the reductions are made at the end of the season, when the data available are complete.

The Public Works Bench-mark is the top of a drift bolt at the side of the shore road, on a line with the centre of the Breakwater, at 56 feet from its shore end. The change in its elevation for the reasons explained, was from 115·55 to 117·05 feet.

A new Bench-mark was established by the Tidal Survey on the masonry foundation of the lighthouse; a chiselled step marked with a broad arrow below it, at the middle of the east side of the lighthouse, and 7 inches above the ground.

	Elevation.
Public Works Bench-mark, as described	117·05
Tidal Survey Bench-mark on lighthouse	116·88
Highest High Water in the season of 1914, on October 22	100·50
High Water ordinary Spring tides (P.W. dept.)	100·00
Average level of High Water at nine Spring tides during the season of 1914, from June to October	99·58
Average level of Low Water at the nine Spring tides during the season	95·55
Low Water ordinary Spring tides, at 5 feet below High Water; adopted as datum	95·00
Lowest Low Water in the season of 1914, on October 24	94·70

Richibucto.—The tide gauge was situated at the Breakwater at the north beach. The Life Saving station is behind it. As there is no masonry on which a Bench-mark can be placed, three reference points were established for security, as follows:—

(1) Public Works Bench-mark; a spike in top of pile, in the south-west row, at 70 feet from north-west end of the extension of 1910; which extends south-eastward from the north pier.

(2) Reference point on floor of the Coxswain's house at Life Saving station; the surface of the hardwood floor just inside of door jamb.

(3) A spike in top of pile, near the tide gauge co. ı as placed in 1914.

	Elevation.
No. 1. Public Works Bench-mark	108·10
No. 2. Surface of floor as described	108·07
No. 3. Spike at tide gauge	106·59
Highest High Water in the season of 1914, on September 26	101·10
Next highest, on October 22 (approximate)	100·90
High Water ordinary Spring tides (P.W. dept.)	100·00
Average level of High Water at nine Spring tides during the season of 1914, from July to October	99·81
Average level of Low Water at the nine Spring tides during the season	96·41
Low Water datum of the Public Works department, adopted by the Tidal Survey	96.00
Lowest Low Water in the season of 1914, an October 24	95.70
Bottom of dredged channel, at 13 feet below datum	83·00

Shediac bay.—The tide gauge was placed at Point du Chêne, in a basin near the Breakwater. The original Public Works Bench-mark at the outer end of the breakwater is now destroyed; but fortunately its elevation was obtained by the Geodetic survey. The difference between the elevations of the Geodetic survey and the original construction levels here, was thus found to be 98·64 feet, which enables the Geodetic Bench-mark to be used for reference in the Public Works levels.

The Geodetic Bench-mark is on the Intercolonial railway round-house at Point du Chêne; a chisel line on a copper bolt set horizontally into fourth cut stone above the ground, on south side of entrance to the round-house; and marked C.—B.M.—M.CCCC.LXXIV. Its Geodetic elevation is 13·87 feet, and

consequently its elevation in the Public Works series is 112·51 to accord with the difference above indicated.

A reference point was also placed by the Tidal Survey near the site of the tide gauge of 1914; a railway spike driven vertically into the top of first mooring post on south side of berthing space between the two projections of the wharf.

	Elevation.
Bench-mark on Round house	112·51
Reference point on mooring post	109·12
Wharf floor, at site of the gauge	106·69
Highest High Water in the season of 1914, on October 22	101·55
Average level of High Water at nine Spring tides during the season of 1914, from July to October	100·48
High Water ordinary Spring tides (P.W. dept.)	100·00
Average level of Low Water at the nine Spring tides during the season	96·28
Lowest Spring tide in autumn, on October 21	96·12
Low-water datum of the Public Works department, adopted by the Tidal Survey	96·00
Lowest Low Water in the season of 1914, on August 5	95·65
Level taken in Geodetic survey as Extreme Low Water (Geodetic elevation,—3·00)	95·64

Characteristics of the tide.—Throughout the south-western side of the Gulf of St. Lawrence, the tide is characterized by a large diurnal inequality, which becomes extreme in the water area south of a line joining Point Escuminac with the North Point of Prince Edward island and extending to Cape Tormentine. This may be considered as the western end of Northumberland strait. It is so dominant a feature in this area, that at Richibucto and Shediac, when the declination of the moon is at all high, north or south of the equator, the tide has a pronounced range once only in the day. An inversion of the inequality also occurs between these two places; for at Richibucto, it is the rise once a day that is pronounced, and the other tides remain near the Low-water level; while in Shediac bay the fall is pronounced, with little variation from the High-water level on the other tides. These features of the tide occur whenever the moon is in high declination.

The large diurnal inequality in the High-water level at Richibucto is thus similar to Caraquet in the mouth of Chaleur bay, to the north; whereas the large diurnal inequality at Low Water is the feature of the tide in the central part of Northumberland strait to the eastward. It appears to be in the area under consideration that this main inversion takes place therefore.

When the inequality is greatest, at the moon's maximum declination north or south of the equator, the tide becomes diurnal; and when there is thus only one High Water and one Low Water in the day, the inequality cannot be expressed as a difference in level between successive tides. The greatest amount of inequality under extreme conditions must therefore be shown by a comparison of the maximum range with the average range, as given below.

Conditions.—Season of 1914.	Richibucto breakwater.	Shediac bay.
	Feet.	Feet.
Greatest range of diurnal tides, with moon at maximum declination south at Spring tides, July 5 to 8	3·90	3·
Greatest range of diurnal tides, with moon at maximum declination north at Spring tides, July 22 to 24	3·29	3·
Spring range at Perigee, with moon near equator, and small remaining inequality eliminated, Sept. 21 to 25	1·90	2·
Spring range at Apogee, with moon near equator, and inequality eliminated, October 4 to 7	1·27	1·
Mean Spring range	1·60	1·

The large range that is possible at times, compared with the true mean rang is thus evident. In establishing levels, it is clear that care is required to obta the limiting conditions; and also to observe the tides both night and day, determine inequalities, when deciding upon a Low-water datum.

Northumberland Strait, and Eastward.

As a feature of the tide, the diurnal inequality continues to be the domina characteristic. In the central part of the strait, it chiefly affects the Lo water level. At Charlottetown, the inequality between the two tides of t day may be greater than the true difference between Springs and Neaps.

Cape Tormentine.—Much trouble has been taken by this Survey and by t District Engineer of Public Works, to maintain the levels here. The origin bolt drilled into the rock, which is a soft red sandstone, was undermined by t sea; and was re-established from reference points on the breakwater. Oth marks have been covered by recent works. It is unnecessary to describe the earlier marks; as it will be sufficient to say that the levels in the old observatio of 1886 and the Tidal Survey observations of 1896, have been maintained by th vigilance until they could be connected in 1914 with the new Bench-mar placed here by the Geodetic survey. All tide levels obtained i[illegible]t, well as in the observations of recent years, have thus become avana..ie [illegible] t important works of the Car Ferry to Prince Edward island.

In the Public Works observations, during periods in the years 1886 to 188 the level of High Water ordinary Spring tides was taken as 100·00 as usu and with a range of 7 feet 8 inches, the level of Low Water ordinary Spri tides was 92·33 feet. This was also adopted as the Low-water datum in t Tidal Survey observations of 1896, as well as in the later observations in t seasons of 1915, 1916 and 1917.

The range by which this Low-water datum was established, seems to ha been based on the greatest ranges observed during the later years of the observations. These ranges were, in 1887 on May 10, 7·67 feet; in 1888 June 25, 7·70 feet; and on September 7, 7·60 feet.

The Public Works Bench-mark of 1906, re-establishing the original o is an iron bolt in the rock at the shore end of the Breakwater on the south si

As this was likely to be covered by rock embankment for the Car Ferry works, the tide levels were carried by the Tidal Survey in 1914 to the following Geodetic Bench-marks:—

No. M.CCCC.XXXIX. In stone foundation at centre of east face of the Cape Tormentine lighthouse. Geodetic elevation 24·13 feet.

No. M.CCCC.XL. In top course of the stone foundation of the Seaside House, on the east side wall, at 22½ feet from the rear end and almost at ground level. Geodetic elevation 13·18 feet.

	Elevation.
Geodetic Bench-mark on lighthouse	121·01
Geodetic Bench-mark on Seaside House	110·06
Public Works Bench-mark; bolt in rock	104·10
Flooring of the breakwater. Original construction level	104·00
Highest High Waters in the different years:—	
Public Works observations of 1886, on December 14	101·60
" " of 1887, probably on January 26	101·65
Tidal Survey; season of 1915, on December 10	101·65
" season of 1916, on December 25	101·65
" season of 1896, on September 20	100·20
High Water ordinary Spring tides, as established by the Public Works department	100·00
Average level of High Water at 12 Spring tides during the season of 1915, from June to December	99·92
Average level of Low Water at the 12 Spring tides during the season of 1915	92·71
Low Water ordinary Spring tides; the datum established by the P.W. department in 1886, and adopted as datum by the Tidal Survey	92·33
Lowest Low Waters in the different years:—	
Public Works observations from August 1886 to February 1887; lowest on November 29	93·10
Public Works observations of 1887, from May to December; lowest Low Water	91·90
Tidal Survey observations of 1896; lowest on September 11 and 26	92·50
Tidal Survey; season of 1915, on October 13	91·85
" season of 1916, on July 15	91·35

In the Public Works observations of 1887, from May to December, there were 17 tides which reached elevation 100 or over, and in the observations of 1888 from June to December, there were 16 of these; but in that season none of the tides reached the extremes above given.

In the Tidal Survey observations, the tide scales were set low, in accordance with the usual practice, to obtain the extremes; and in each season the height of the datum on the scale was accurately known from the levels. It is unnecessary to give the elevation of their zeros however, as they no longer exist; and a working scale can always be set with reference to the Bench-marks.

Port Borden.—Formerly, Carleton head; the Car Ferry terminal on Prince Edward island, opposite to Cape Tormentine. The Low-water datum here was determined arbitrarily for the Car Ferry works; but the tidal observations

since obtained show it to be in good correspondence with the Low-water datu at Cape Tormentine. The comparison is as follows, relatively to the Avera level of Low Water at Spring tides in 1915, from simultaneous observations the two places:—

Datum, Cape Tormentine, below this average level..... 0·38 foot.
Datum, Port Borden, below this average level..... 0·23 foot.

The Bench-mark, placed by the Car Ferry engineers in March, 1915, is t top of a bolt set in the rock, immediately east of the point where the embau ment of blocks for the Ferry pier meets the bank. Height above Low-wat datum, 11·68 feet. Taking the Spring rise here as 7·50 feet, which correspon relatively with the rise taken for Cape Tormentine, and the elevation 100· for High Water as thus obtained, the tide levels are as follows:—

	Elevati
Bench-mark, as described	104·
Highest High Water in the autumn of 1914, on October 22	101·
Highest High Waters in the season of 1915, on August 18 and November 9	100·
High Water ordinary Spring tides, at 7·50 feet above the Low-water datum	100·
Average level of High Water at 14 Spring tides, in October 1914, and from May to November in 1915	99·
Average level of Low Water at 12 Spring tides in the same period	92·
Low Water datum, at 11·68 feet below the Bench-mark	92·
Lowest Low Waters in the season of 1915, on May 16 and October 13	91·

Port Elgin.—This harbour is at the head of Baie Verte, in the mouth the Gaspereau river. The original Bench-mark here was a large stone, simil to a boundary stone, set deeply into the ground, beside Fort Moncton; but has been taken out of the ground and removed.

Public Works Bench-mark.—A broad arrow cut on a masonry foundati pillar, under the south corner of the warehouse of the Port Elgin Trading co pany. It is cut flat, on a levelled surface on top of the pillar at its southwe side, at two feet above the ground.

Geodetic Bench-mark.—A copper bolt in a foundation pillar of this wa house, at 24 feet from its front side; marked C.—B.M.—M.CCCC.XLVI. Geodet elevation, 11·59 feet.

This warehouse is immediately behind the Port Elgin station building, a its south-east side is 85 feet from the centre of the track.

	Elevati
Public Works Bench-mark, as described	108·
Geodetic Bench-mark, as described	108·
High Water ordinary Spring tides (P. W. dept.)	100·
Low Water ordinary Spring tides, the datum of the Public Works department	91·

These tide levels are correlated with Cape Tormentine, by means of t half-tide level at the two places, with allowance for the difference of rang which is here 17 per cent greater.

Summerside, P.E.I.—A Bench-mark was established here by Commander Tooker, R.N. to define the Low-water datum for the Admiralty surveys made under his direction previous to 1901. It is a large broad arrow of sheet copper placed on a pile on the east side of the Government wharf, nearly abreast of the lighthouse.

For greater permanence it was deemed advisable to connect the level of this mark with a reference point on one of the few masonry building in the town. The point thus selected as a Bench-mark is at the north-east corner of Holman's block; the joint between the stone foundation and the brickwork, at the top of the course which forms the door-step level all along the street front of the building. This Bench-mark was used for reference in the tidal observations obtained in 1901, from July 12 to November 15.

	Elevation
Bench-mark on Holman's block, as described	100·00
Exceptional High Water; night tide on October 11, 1900, the autumn before the observations. Six points marked at different places in the harbour as the level reached by the water, were found to range in elevation from 90·07 to 90·31. Mean value	90·20
Highest High Water in the season of 1901, during a storm on November 14	87·60
Highest High Water in the season, undisturbed by storms, on June 17	87·30
Bench-mark established by Commander Tooker, the broad arrow as as described	87·30
Lowest Low Water in the season of 1901, on October 30	80·10
Admiralty Low-water datum, defined as 7·60 feet below the broad arrow. Adopted also as datum by the Tidal Survey	79·70

A table showing the levels reached by High and Low Water during the season of 1901, from simultaneous observations at St. Paul island, Pictou, Charlottetown and Summerside, is given in the Report of Progress of the Tidal Survey for 1902, page 15.

Pictou.—This was made a secondary reference station in the early years of the Survey, as it is centrally situated in Northumberland strait. The tides for Pictou were calculated from St. Paul island; and from these, in turn, the Charlottetown tides were calculated. As the methods of calculation were very complex, it was found better to make Charlottetown a principal tidal station; and the simultaneous observations obtained at the two places during several seasons, afforded a basis for computing the Pictou tides from Charlottetown.

Because of these objects, tidal observations were obtained at Pictou during the seasons of 1896, 1897, 1901, 1903, 1907, 1908, 1914, and 1915; but it was not equipped as a permanent station for winter observations. The Low-water datum was determined from the tidal record in the first three seasons, in January 1902, for both Pictou and Charlottetown. In doing so, special care was taken to deal satisfactorily with the large diurnal inequality, as there are times when the two Low Waters of the day may differ by 4¼ feet. A special table is given below to show the relation of the datum to the average level of Low Water

at Spring tides. A list of the extreme tides is also given for both places, as well as the recent determinations of Mean Sea level, which now enable the two independent sets of elevations to be correlated.

The highest and lowest tides here given will therefore be limited to years in which simultaneous observations were obtained elsewhere. They also show the limiting values which ordinary seasons may afford.

The tide scales used in the different seasons were not always at the same level, sometimes being purposely altered to obtain a better position for the tide curves on the recording instrument. But the true elevation of the zero of the scale in each season was accurately known; and all the levels are thus reduced to a consistent series of elevations, making it unnecessary to publish the various zero levels of the tide scales in the different years.

The original Bench-mark of 1896, was the surface of the stone door-sill at its west end, in the doorway of the Custom House building which faces the harbour. The sill was lowered nearly 2½ feet in 1907, in cutting down the doorway to a new level during alterations to the station yard adjoining; but the original level of the sill is marked by a broad arrow cut on the masonry at the west side of the doorway, with the words "Tidal Survey Bench Mark" cut above it. There are now two Geodetic Bench-marks also in this vicinity, as follows:—

Geodetic Bench-mark, C.—B.M.—MCC.LXXX.IX. On the end of the Custom House which faces the harbour, to the west of the doorway above described. Geodetic elevation, 15·34.

Geodetic Bench-mark, C.—B.M.—MCC.LXXX.VIII. On foundation of Railway station, at west end; at 7feet from the south-west corner. Geodetic elevation, 13·28.

	Elevation.
Tidal Survey Bench-mark established in 1896, as above described.....	100·00
Geodetic Bench-mark on Custom house.....	99·85
Geodetic Bench-mark on Railway station.....	97·79
Extreme High Water of December, 1889.....	90·86
Highest High Water in the season of 1896, from June 3 to November 27; occurred during a storm on November 6.....	88·35
Highest High Water in the season of 1901, from May 20 to November 15; occurred on October 1.....	87·85
Highest High Water in the season of 1903, from May 8 to October 31; on July 28.....	87·74
Highest undisturbed in this season, on August 25, to compare with Charlottetown.....	87·62
Average level of Low Water, at twelve Spring tides during the season of 1901 from May to October.....	81·48
Low-water datum determined as explained, and adopted in 1902..... (The lowest Low Waters in the seasons of 1896, 1901 and 1903 are given in the list of extreme tides.)	81·40
Lowest level of Low Water yet obtained. In 1914 on November 19.....	80·00

Ratio of range of tide, Pictou to Charlottetown.—This ratio was determined from the ranges of all tides, taken simultaneously, during two months in 1903;

one month from June 3 to July 3, having its centre at the solstice, and the other from September 2 to October 2, having its centre at the equinox. The result is as follows:—

Solsticial month.	From 119 ranges. Ratio.....	57 per cent.
Equinoxial month.	From 117 ranges. Ratio.....	58 "
Range at Pictou proportionately to Charlottetown.....		58 "

True mean Spring and Neap ranges in Northumberland strait.—These ranges at Pictou, Charlottetown and Summerside, were obtained from the simultaneous observations of 1901, from June to October; which afforded ten Spring tides and eight to ten Neap tides for comparison. The ranges in all cases are the mean of two consecutive differences in level, between High Water and Low Water, to eliminate the diurnal inequality. For each Spring tide the greatest mean value of these two consecutive ranges is taken; and for each Neap tide, the least mean value. The final averages thus obtained during the whole season are shown in the table below.

Locality.	Average Range.			Percentage relatively to Charlottetown.
	Springs.	Neaps.	Mean.	
	Feet.	Feet.	Feet.	
Pictou.....	4·27	2·14	3·21	60 per cent.
Charlottetown.....	6·91	3·84	5·39	100 "
Summerside.....	4·48	2·86	3·67	68 "

It will be noticed at once how small these true ranges of the tide are, compared with the actual differences in level that can occur because of inequality and storm disturbance, as shown by the tide levels which are given as elevations. The greatest individual ranges during this season, when the diurnal inequality occurred at the Springs in October, were as follows: At Pictou 6·65 feet, at Charlottetown 9·75 feet, and at Summerside 6·60 feet.

The rise of Spring tides above the Low-water datum is from $2\frac{1}{4}$ to $2\frac{1}{2}$ feet greater than these average ranges, because of the large inequality at Low Water; as the datum is necessarily based on the lower of the two Low Waters, for the reasons explained.

Extreme tides at Pictou and Charlottetown.—In the following table of extreme tides the elevations of the marked points mentioned, were obtained by instrumental levels, taken by the Tidal Survey. It is to be noted that the elevations at Pictou and Charlottetown are independent of each other.

EXTREME TIDES AT PICTOU AND CHARLOTTETOWN.

Date and Description.	Elevations of H. W. and L. W.	
	Pictou.	Ch'town.
	Feet.	Feet.
1889. December. Highest tide known at Pictou. Elevation obtained from points indicated by residents	90·86	
1900. December 5, during a gale. From points marked at the time at Pictou, and marked at Charlottetown by the Harbour master.	89·72	95·30
1904. February 3, at noon; weather calm. From a point marked inside shed, unaffected by wash of the waves		95·93
Exceptional level recorded by engineers of the Hillsbrough bridge while taking soundings in the winter of 1901, but date uncertain Probably the same tide		95·90
1908. January 5, at 23:15, during a N.E. gale. As recorded on Tide Gauge at Charlottetown		95·66
Same tide at Pictou, said to be 6 inches higher than in December, 1900. Equivalent elevation	90·22	
1909. December 1; from a point marked at the time at Pictou	90·46	
1914. February 17; as recorded on Tide Gauge at Charlottetown		95·37
Same tide at Pictou, from a point marked by the tidal observer	90·61	
1915. September 27, during a SW. gale. As recorded on Tide Gauge at Charlottetown		95·80
Mean Sea level; approximate value at Pictou. From hourly ordinates during two lunar months in 1896, elevation 84·35; and during two lunar months in 1903, elevation 84·51 Mean (Elevation from Geodetic Survey levels, 84·51.)	84·43	
Mean Sea level at Charlottetown; from hourly ordinates during five complete years between October, 1907 and April, 1913		89·71
1896. June 26; exceptional Low Water as recorded on Tide Gauge at Pictou	80·25	
1897. November 27; on Tide Gauge at Pictou	80·15	
1901. May 20; low level observed by engineers of the Hillsborough bridge		83·03
Same tide at Pictou, as recorded on Tide Gauge	80·02	
1903. June 25, as recorded on Tide Gauge at Charlottetown		83·21
Same tide at Pictou, as recorded on Tide Gauge	80·27	
1914. November 19; as recorded on Tide Gauge at Charlottetown		83·20
Same tide at Pictou; the lowest recorded during the season	80·00	

Average Low Water and Datum; Pictou and Charlottetown.—In the central part of Northumberland strait, the diurnal inequality is very large at times, and it chiefly affects Low Water. The standard method of basing the average upon the one Low Water which is lowest at each Spring tide, takes the diurnal inequality fully into account; as it is always the lower of the two in the day that is included. There is little margin required therefore, between the average as thus found and the Low-water datum adopted. The elevations at Pictou and Charlottetown are independent of each other.

Average level of the lowest Low Water at each Spring tide during the seasons indicated.	Pictou.	Charlottetown.
	Feet.	Feet.
1896. At eight Spring tides, July to November	81·00	84·93
1897. At ten Spring tides, July to November	81·43	
1901. At twelve Spring tides, May to October	81·48	84·96
Low-water datum, adopted in January, 1902, as the zero level for the Tide Tables	81·40	84·80

Charlottetown, P. E. I.

Observations were obtained here in the seasons of 1896, 1901 and 1903; and in October 1907, a permanent tide gauge was established, the observations being thus continuous since that date.

The original Bench-mark of 1896 had 100·00 for its elevation, and the levels were transferred to a better mark in 1901. This new Bench-mark is on a masonry building at the south-west corner of King and Queen streets; the top of the sandstone plinth at the corner, where marked by an inverted broad arrow cut on the masonry above it. The Low-water datum was adopted in 1902, at the same time as the Pictou datum, as there explained.

	Elevation.
Bench-mark of 1901, as above described	103·18
Cap of wharf at site of tide gauge	96·61
Exceptional High Water of February 3, 1904; highest recorded. (See details in list.)	95·92
Highest High Water in the season of 1896, during a storm on November 6	93·90
Highest High Water in the season of 1901, from May 30 to November 15 occurred on October 1	93·95
Average level of High Water at 24 Spring tides in each of the two complete years, 1908 and 1909	93·47
Mean Sea level; from the hourly ordinates of the tide during five complete years between October 1907 and April 1913. (See details given below)	89·71
Average level of Low Water, at twelve Spring tides in the season of 1901 from May to October; three missing tides being interpolated to give a truer average	84·96
Low-water datum determined as explained, and adopted in 1902	84·80
Lowest Low Water recorded by the tide gauge in the season of 1896; a number in the early part of the season being lost. Occurred on October 9	84·35
The lowest Low Waters in the seasons of 1901 and 1903 are given in the list of extreme tides; the lowest being the exceptional Low Water of May 20, 1901	83·03
Zero of tide scale from 1907 to 1910, 79·99 to 79·97. As re-set in September 1910	80·00

Mean Sea level at Charlottetown.—Determinations have now been obtained from the hourly ordinates of the tide, during seven complete years, as here given. The values are above the Low-water datum, which is at elevation 84·80

	Feet.
One year from October 1907 to October 1908	4·817
" October 1908 to October 1909	4·968
" October 1909 to October 1910	4·989
" April 1911 to April 1912	4·832
" April 1912 to April 1913	4·960
" April 1913 to April 1914	4·903
" April 1914 to April 1915	4·854

The Low-water datum was of service when the drainage system of Charlottetown was [illegible]. The accurate determination of Mean Sea level now available, is [illegible] as a basis for the extended levelling which is being carried over the [illegible] Edward island.

Georgetown, P.E.I.—Tidal observations were obtained here in 1908, from June to November. The Bench-mark is on the foundation of the Court House; a broad arrow on the right side of the main entrance, cut on the brown sandstone of the foundation, at about 20 inches from the ground.

	Elevation.
Bench-mark as described	100·00
Exceptional High Water which occurred in the autumn of 1914 or 1915, in calm weather after a South-west gale	68·75
Highest High Water in the season of 1908, on October 30	67·70
Average level of High Water at twelve Spring tides during the season of 1908, from June to November	66·71
Average level of Low Water at the twelve Spring tides during the season	61·31
Low-water datum, as adopted	60·86
Lowest Low Water in the season, on August 13	60·70

Souris, P.E.I.—Tidal observations were obtained here in the seasons of 1896 and 1903. For reference in the earlier observations a Bench-mark was established on a sandstone cliff and marked with the letters "B.M.", but in 1903 this had been destroyed by quarrying for building stone. The Low-water datum of 1903 was carried back to 1896 by assuming that the Average level of Low Water at Spring tides in the two seasons was the same; and the tide levels of 1896 have thus been correlated with the later observations.

A new Bench-mark established in 1916, is at the south corner of the Post Office building; a chisel line on the end of a brass bolt set horizontally into the sandstone of the corner abutment at 26 inches above the concrete sidewalk, and marked with the letters "B. M."

Reference Bench-mark of 1917, on Railway wharf. The surface of the concrete on the south side of the wharf, just behind the guard timber, at 5½ feet from the inner end of the straight face of the wharf.

As both the Bench-marks of 1896 and 1903 had unfortunately been destroyed, the tide levels were correlated with these new Bench-marks by observations

of High Water in calm weather at Souris, Georgetown and Charlottetown, simultaneously. The relation of these special tides to the Average level of High Water at the three localities was assumed to be the same. At Souris, the height of this average level above datum was known to be 5·13 feet, from the observations of 1896 and 1903. This difference of level enabled the Low-water datum at Souris to be correlated with the new Bench-marks. The resulting tide-levels are as follows: –

	Elevation.
Bench-mark on Post Office, as described	142·00
Reference Bench-mark on Railway wharf	102·12
Top of ring bolt used as working Bench-mark during observations of 1903; removed in altering approach to McLean's wharf	100·00
Exceptional High Water which occurred in the autumn of 1914 or 1915, in calm weather after a south-west gale. Same tide as described at Georgetown	99·65
Highest High Water in the season of 1896, from July to November; on November 6	98·95
Highest High Water in the season of 1903, from June to October, on July 27	98·30
Average level of High Water at 16 Spring tides: seven in the season of 1896 and nine in the season of 1903	97·63
Average level of Low Water at nine Spring tides during the season of 1903	92·83
(Average level of Low Water at six undisturbed Spring tides in 1896, assumed to be at the same elevation.)	
Low-water datum adopted	92·50
Lowest Low Water in the season of 1903, on September 19	92·60
Exceptional Low Water in the season of 1896, on November 5	92·15

Port Hood, N.S.—Tidal observations were obtained here in 1915, which were simultaneous with Pictou and Cheticamp.

The Bench-mark is on the masonry foundation of the brick church which stands on the high ground above the wharf. It is a projecting ledge of the first course of masonry above the ground, in one of the pair of buttresses at the west corner of the building. Being so high above the water, its elevation is taken as 160 feet.

	Elevation.
Bench-mark, as described	160·00
Highest High Water in the season of 1915, on September 27	78·85
Average level of High Water at twelve Spring tides during the season of 1915, from May to November	76·76
Average level of Low Water at the twelve Spring tides during the season	72·34
Low-water datum, adopted to correspond with the datum at Souris and Georgetown, in relation to the average level of Low Water	72·04
Lowest Low Water in the season of 1915, on June 28	71·65

Cheticamp, N.S.—Tidal observations were obtained here in 1915, in the bay inside of Cheticamp island, known as Eastern harbour. The Bench-mark is

on the church which stands a short distance south of the Government wharf; on the masonry sill of the basement window nearest the front of the building, on the north side; the point used as a Bench mark being the level surface at the top of the weather slope, next the inner sill of wood.

	Elevation.
Bench-mark as described	100·00
Highest High Water in the season of 1915, on September 27	69·55
Average level of High Water at twelve Spring tides during the season of 1915, from May to November	67·89
Average level of Low Water at the twelve Spring tides during the season	64·22
Low-water datum, adopted to correspond with the datum at St. Paul island	63·96
Lowest Low Water in the season of 1915, on June 28	63·50

Note on Low-water datum in the eastern end of Northumberland strait.—In deciding on the elevation of the datum relatively to the Average level of Low Water at Georgetown, Souris, Port Hood, and Cheticamp, comparisons were made with the Average level of Low Water at St. Paul island in the same seasons, as the observations there are continuous. These comparisons brought to light any variations in this average level between one season and another; and in the comparison between one of these localities and another, the difference of range was considered, with regard to the margin between Average Low Water and datum. The datum adopted for these localities was thus made consistent, and brought into good accord with the reference station for the region, at St. Paul island.

Prince Edward Island.—North coast.

Simultaneous observations were obtained at ports along the whole extent of this coast in 1916, from Tignish to Naufrage. The leading feature in the tide is diurnal inequality, which is here so highly developed that the tide becomes diurnal when the moon is at its maximum declination. At such times there is only one High Water and one Low Water in the course of the day, the other two being then effaced. The extreme ranges therefore occur when the moon is at its maximum declination at the Spring tides. It was also found best to base the Average levels of High and Low Water upon the two highest and two lowest consecutive tides at the time of the Springs.

The shore is usually flat and sandy, and any rock is a very soft red sandstone. The harbours and wharves are generally a mile or two distant from the towns whose names they bear, and there were therefore no masonry buildings in their vicinity. In establishing Bench-marks, it was therefore best to erect a concrete column, which went down to the rock or well below the depth of frost. These afford good permanent Bench-marks along this coast; as any Public Works Bench-marks there, are on timberwork.

Tignish.—The works here consist of a pair of parallel piers which form a "Run" through the sand bar, and serve as wharves for loading or unloading vessels. The Public Works Bench-mark is the top of the cap at a break in

the line of the piling about the middle of the run on the northeast side, and the Low-water datum is defined as 7 feet below this Bench-mark.

The new Bench-mark of 1916, is the top of a brass bolt set vertically in a concrete column 25 feet east of the south-east corner of the lighthouse for the back range light.

	Elevation.
Reference mark on the Post Office building in the town of Tignish; the top of the sandstone foundation, (on stone next by one to the corner) on south side of the tower	159·65
Railway Bench-mark; the surface of the concrete sidewalk at end of track of Prince Edward island railway, main line	154·13
New Bench-mark, on the concrete column at the harbour	100·00
Surface of cap, at the head of the breakwater which extends from the north-east side of the Run	100·35
Flooring, at head of breakwater	99·68
Public Works Bench-mark, as described	98·41
Extreme High Water of November 20, 1914; from its level on the side of the lighthouse and on a neighboring building. Approximately	99·50
Highest High Water in the season of 1916, on July 14	96·15
Average level of High Water at eight Spring tides during the season of 1916, from June to October	95·03
Average level of Low Water at the eight Spring tides during the season	91·75
Low-water datum of Public Works department	91·41
Lowest Low Water in the season of 1916, on September 11	90·90

Alberton.—The Public Works Bench-mark was the top of a corner pile at the end of the Railway wharf; but it has settled seriously, probably more than two feet. The Low-water datum was therefore re-determined from the tidal observations. The tide gauge was placed at the Government wharf, the second from the Railway wharf.

The new Bench-mark of 1916, is the top of a brass bolt set vertically in a concrete column at the intersection of the Railway right-of-way and the inner side of the shore road; opposite the shore end of the Railway wharf.

	Elevation.
Tidal Survey Bench-mark, on concrete column	100·00
Cap of wharf over tide scale of 1916	93·92
Extreme High Water of November 1914; from mark pointed out by residents. Approximately	91·60
Highest High Water in the season of 1916, on October 14	90·00
Average level of High Water at ten Spring tides during the season of 1916, from June to October	88·65
Average level of Low Water at the ten Spring tides during the season	85·39
Low-water datum, as determined by the Tidal Survey to accord with the others along this shore	85·13
Lowest Low Water in the season of 1916, on July 14	84·70

The Public Works datum, if taken as 9·00 feet below the present elevation of their Bench-mark, would be 2½ feet lower than the datum as here given.

As it was no doubt in accord with Low Water originally, the settlement of the Bench-mark must have been two feet at least.

Malpeque, P.E.I.—The tide gauge was placed at the pier recently built in front of the village of Malpeque. It is known as Kier's Shore pier, situated in March Water, a sheltered area 7 miles inside the eastern entrance of Richmond bay. The dredged channel which leads to the pier, will have a depth of 10 feet below Low Water.

The Bench-mark of the Public Works department, is the top of the cap at the end of the pier near the south-east corner. It had been found difficult, with this type of tide, to decide upon a satisfactory datum for the dredging; but after obtaining the tidal observations of 1916, the question was discussed with the District Engineer of Public Works at Charlottetown. It was decided to place it one foot lower than the Low-water datum as here adopted by the Tidal Survey; and it is accordingly defined as at 9·10 feet below the Public Works Bench-mark.

The new Bench-mark established, is the top of a brass bolt set vertically in a concrete column, at the corner of Dr. Kier's property, near the shore end of the pier.

	Elevation.
Tidal Survey Bench-mark, on concrete column	100·00
Public Works Bench-mark; cap of pier in 1916	98·45
Highest High Water in the season of 1916, on July 14	95·05
Average level of High Water at seven Spring tides during the season of 1916, from end of June to beginning of October	94·12
Average level of Low Water at the seven Spring tides during the season	90·62
Low-water datum, as adopted by the Tidal Survey, to accord with the others along this shore. (At 1·00 foot on the tide scale of 1916)	90·37
Lowest Low Water in the season of 1916, on July 14	89·80
Public Works datum for dredging; at 9·10 feet below their Bench-mark. (At zero of the tide scale of 1916)	89·35
Zero of Tide scale, at 10·65 feet below the Tidal Survey Bench-mark.	89·35
Bottom of dredged channel, at 19½ feet below the Public Works Bench-mark	79·00

Rustico.—This harbour is protected by two breakwaters, at the two sides of the entrance. The tide gauge was placed at the end of the cribwork that runs out from the front range light. It was thus 1,200 feet inside the line of the breakwaters.

The Public Works Bench-mark is the top of the cap at outer end of the northern breakwater which extends from Churchills Point. The Low-water datum is at 8 feet below the Bench-mark; and this was accepted by the Tidal Survey. On the Public Works plans, the rise of the tide above this datum is given as Springs, 4 feet; Neaps, 2 feet; but this was found to be too little, as the levels will show.

The new Bench-mark is the upper side of a brass bolt set horizontally into the side of a concrete column; at 25 feet east of the front range lighthouse, in line with its north side.

	Elevation.
Tidal Survey Bench-mark; in the side of concrete column, as described	100·00
Public Works Bench-mark, on breakwater	95·43
Extreme High Water, from mark pointed out by residents	93·65
Highest High Water in the season of 1916, on October 14	92·60
Average level of High Water at eleven Spring tides during the season of 1916, from June to October	90·93
Average level of Low Water at the eleven Spring tides during the season	87·54
Low-water datum, Public Works department, at 8·00 feet below their Bench-mark; accepted by the Tidal Survey	87·43
Lowest Low Waters in the season of 1916; on June 16 and July 15	86·75

St. Peters harbour.—This harbour is protected by two short breakwaters at the entrance to the bay, extended as sand breaks. The tide gauge was placed inside the head of the west breakwater along which the fish-houses are situated.

The Public Works Bench-mark is the cap on the north side of the breakwater, near the shore end, opposite the fish-houses. The Low-water datum was defined as 8·51 feet below this Bench-mark; but the observations of 1916 showed this to be 0·65 too low, relatively to the others along this shore. The District office of the Public Works department preferred to alter the elevation of the Bench-mark by this amount, namely from elevation 104·51 to 103·86; in order to retain the elevations 100·00 and 96·00 for High and Low Water respectively, in their series. The Low-water datum as adopted, is therefore at 7·86 feet below this Bench-mark.

The new Bench-mark is the top of a brass bolt set vertically in a concrete column at the inner side of the sand barrier which extends inland from the breakwater; and at a distance of 312 feet west of the lighthouse.

	Elevation.
Tidal Survey Bench-mark, on concrete column	100·00
Public Works Bench-mark, as described	97·13
Level said by residents to be reached by extreme High Water (approximate)	96·05
Highest High Water in the season of 1916, on October 14	94·15
High Water ordinary Spring tides, of the Public Works department; ar 4 feet above datum, and corresponding to the new elevation of 100·00 in their levels	93·27
Average level of High Water at ten Spring tides during the season of 1916, from June to October	92·58
Average level of Low Water at the ten Spring tides during the season.	89·54
Low-water datum as determined by the Tidal Survey and adopted by the Public Works department	89·27
(This is 0·65 higher than datum formerly shown on Public Works plans, and corresponds to new elevation of 96·00 in their levels.)	
Lowest Low Water in the season of 1916, on July 15	88·95

Naufrage.—The works here consist of a pair of guide piers which form a "Run" through the sand bar. An entrance is thus maintained to the pond inside the bar. There are no Public Works levels here.

This locality was selected as a tide station as being the nearest available to the east end of Prince Edward island. Along the north coast generally the range of the tide is greatest at the west end, and decreases eastward. By having a station as far east as this, it was ascertained that the least range occurs at St. Peters, and that it increases again slightly at Naufrage.

The Bench-mark of 1916, is a chisel line ½ inch deep, with a broad arrow below it, cut on the concrete foundation of the lighthouse on its south-west side near the west corner.

	Elevation.
Bench-mark, as described	100·00
Level said by residents to be reached by extreme High Water in storms (approximate)	57·40
Highest High Water during the observations of 1916, up to the end of September; on August 14	55·65
Average level of High Water at six Spring tides during the season of 1916, from July to September	54·96
Average level of Low Water at the six Spring tides during the season	51·67
Low-water datum, as adopted by the Tidal Survey	51·36
Lowest Low Water in the season of 1916, on July 15	50·55

Summary of Rise and Datum levels.—In the following table, the rise given is from the Low-water datum as adopted. The extreme difference of level is from the record of the tide gauge during the period of the observations only. In comparing the values it is to be noted that Malpeque is in a more land-locked bay and further from the open coast than the other tide stations. Also, at Naufrage the season was shorter, and the extreme difference of level does not include the highest High Water of October.

Locality.	Spring rise.	Neap rise.	Extreme difference of level.	Datum below Average L. W. at Springs.
	Feet.	Feet.	Feet.	Foot.
Tignish	3·62	2·67	5·25	0·34
Alberton	3·52	.....	5·30	0·26
Malpeque	3·77	2·80	5·25	0·27
Rustico	3·50	2·56	5·85	0·11
St. Peters	3·31	.....	5·20	0·27
Naufrage	3·60	2·93	5·10	0·31

St. Paul Island, Cabot Strait.

This tidal station is situated in Cabot strait, which forms the main entrance between Cape Breton and Newfoundland by which the tides enter the Gulf area from the Atlantic. It has proved an invaluable reference station, as the

tides on the greater part of the Gulf shores can be referred to it, as well as the turn of the current in several important straits. The continuous observations from year to year afford the means of correlating the Low-water datums at the summer stations of different seasons, as well as comparing the ranges.

The tide gauge is built into the cliffs and protected by crib-work, as there are no artificial facilities; and although constructed largely of ironwork and concrete, it was once carried away, and has twice been rebuilt. The levels have been maintained continuously, however, and a uniform datum has been used throughout in the reduction of the observations.

In the early observations unusual difficulties were met with, chiefly from want of communication in winter, so that breaks in the record occurred. From 1893 to 1897 only one complete year of unbroken observations was obtained. The Low-water datum was decided upon in 1897, after a sufficient amount of tidal record was obtained, and it was carried back to the beginning. From 1898 onward, good observations have been obtained, with interruptions of four to six months at times owing to damage or during repair.

The tide house was originally set at twelve feet above High Water; but this was found insufficient to secure it from the reach of the waves, in so exposed a situation. When it was carried away in the storm of February, 1895, it was rebuilt at 25 feet above High Water, for greater security. When any accident occurred to the clock of the recording instrument, especially if in winter, an interruption of some months might occur before the clockwork could be sent to some city for repair and be returned. A special type of recording instrument was therefore designed for such isolated localities, in which the driving clock was interchangeable with a duplicate one. There were similar difficulties at first in obtaining correct time for the observations.

Because of these difficulties, summer stations were established on the two sides of Cabot Strait in 1901, in northern Cape Breton and near Cape Ray, to see whether the reference station could not be placed on the mainland. Neither of these proved as suitable, however, since the tide is quite free from local disturbance at the St. Paul island station, which is within four miles of the 100-fathom line. It was also evident by that date that St. Paul island would prove an invaluable reference station for a large part of the Gulf area, and a change would be disadvantageous, since it it so well situated to command C[illegible]ot strait. When the gauge was seriously damaged in Janaury 1902, it was therefore decided to restore it.

A troublesome feature in the record obtained was the wave motion which is superposed on the tide curves during storms. This was largely overcome in 1907, when the main iron cylinder of the gauge was renewed. It was enlarged to a diameter of four feet at the lower end, to enable reservoir pipes to be introduced between the inlet from the sea and the tide pipes, by which the wave motion was further reduced. This is a matter of importance, when it is possible for the waves to have a geater amplitude than the whole range of the tide.

The original Bench-mark was the iron pillar of the dipleidoscope, set at the top of the cliffs. This is an instrument by which true time for the observations can be obtained direct from the sun. The elevation of this Bench-mark was taken at 100·00 feet. This, and other marks on the rocks, were used for convenience; but the elevation of the permanent Bench-mark only need be

given. It is the top of a brass bolt set vertically in a level bench of rock between the tide gauge and the sea.

	Elevation
Floor of Tide house, on top of iron cylinder of the tide gauge, as in 1902	49·08
Permanent Bench-mark, as described	37·55
Extreme High Water of December 16, 1916	25·90
Exceptional High Water of February 17, 1914	25·77
Average level of High Water, from twelve Spring tides in the season of 1915, from May to November	23·63
Average level of High Water at the Neaps, from twelve Neap tides in each of the two seasons of 1901 and 1903	22·46
Mean Sea level; from the hourly ordinates of the tide during fifteen complete years, between 1897 and 1914. (See details given below.)	21·93
Average level of Low Water at Spring tides; the mean value from two complete years, and two seasons determined for comparative purposes; being 0·66 foot above the Low-water datum as adopted	20·22
Low-water datum, as adopted in 1897, and maintained throughout the observations	19·56
Lowest Low Water in the season of 1901, on May 20; at same date as exceptional low at Pictou and Charlottetown	19·32
Exceptional Low Waters of March 21, 1912 and March 23, 1913	18·80
Extreme Low Water of February 2, 1915	18·45
Bottom of iron cylinder of the tide gauge	16·17

Mean Sea level at St. Paul island.—The long series of years at this station will serve to indicate the variation in Mean Sea level on the Atlantic coast. The earlier years are simultaneous with Halifax up to 1906; and the later years will supplement the series obtained there.

The determinations are from the hourly ordinates of the tide measured from the Low-water datum which has been maintained throughout at a constant elevation; and each determination is for a complete year, the interruptions between them occurring as indicated. The Low-water datum is at elevation 19·56 feet.

	Feet.
One year, from October 1895 to October 1896	2·538
" December 1897 to December 1898	2·436
" May 1899 to May 1900	2·343
" May 1900 to May 1901	2·339
" August 1902 to August 1903	2·260
" August 1903 to August 1904	2·311
" August 1904 to August 1905	2·302
" December 1905 to December 1906	2·231
" December 1906 to December 1907	2·282
" May 1908 to May 1909	2·387
" May 1909 to May 1910	2·431
" May 1910 to May 1911	2·468
" May 1911 to May 1912	2·371
" May 1912 to May 1913	2·424
" May 1913 to May 1914	2·411
General average, giving elevation 21·93 feet for Mean Sea level	2·369

Port aux Basques, Nf'd.—This harbour is practically at Cape Ray, and thus represents the tide on the north-east side of Cabot strait. Tidal observations were obtained here in 1901, from July 9 to November 1. For the tide levels, the point made use of as a Bench-mark, is the top of an iron eye-bolt let into the rock, at six feet west of the north-west corner of E. Pike's fish store, at the head of the Government wharf.

	Elevation.
Bench-mark, as described	100·00
Highest High Water in the season of 1901, on September 30	93·95
Average level of Low Water at eight Spring tides during the season	88·81
Low-water datum adopted	88·60
Lowest Low Water in the season of 1901, on October 29	88·25
Next lowest, during a storm on August 2	88·30

St. Ann harbour, N.S.—Situated in the main angle of the north-east coast of Cape Breton island, near the entrance to the Bras d'Or lakes. Tidal observations were obtained here in 1915, from July to October.

The Bench-mark is a brass bolt set vertically into a large boulder, almost buried in the sand, near the High-water mark; at 72 feet north-west from the shore end of the wharf at Munroe point.

	Elevation.
Bench-mark, as described	100·00
Highest High Water in the season of 1915, from July to October; on September 27	100·95
Average level of High Water at six Spring tides during the season	99·01
Average level of Low Water at seven Spring tides during the season	94·91
Lowest Low Water in the season of 1915, on October 13	94·40
Low-water datum, adopted to accord with the datum as established at Sydney, relatively to average Low Water there	94·26

Sydney, N.S.—Tidal observations were obtained here for one full month in 1901, during the progress of the simultaneous series at Port aux Basques, Pictou, Charlottetown and Summerside. Further observations were obtained during the season of 1915, from July to October. In both years, the registering tide gauge was placed at the Intercolonial railway wharf at Battery Point.

In 1901, a Bench-mark was established on the old Court House at the corner of Charlotte and Desbarres streets, with relation to the City datum.

In 1915, this Bench-mark was found to be buried under masonry, as the building was being demolished. Another Bench-mark was therefore established on the new Court House building; a brass bolt set horizontally into the champfered course of the foundation, in west face of wing on north side of the building.

The City datum was accepted for tidal purposes, to avoid introducing any new system. It is approximately the level of extreme Low Water. The elevations of both the Bench-marks established in 1901 and 1915, were determined from City Bench-marks, in the neighborhood. In the elevations here given, the City datum is taken as 100·00 instead of zero; which gives the same figures as for City levels.

	Elevation.
Bench-mark of 1915; the upper side of the brass bolt, as described. . .	140·77
Cap of Wharf at site of tide gauge of 1901	110·43
" " 1915	110·48
Highest High Water during the season of 1915, from July to October; on September 27	106·10
Average level of High Water at seven Spring tides during the season of 1915	104·79
Average level of Low Water at the three Spring tides recorded in the observations of 1901, from July 4 to August 6	100·70
Average level of Low Water at the seven Spring tides during the season of 1915	100·65
Lowest Low Water during the observations of 1901, on July 16	100·10
Low-water level adopted as datum for City of Sydney; and accepted as datum by the Tidal Survey	100·00
Lowest Low Water in the season of 1915, on July 26	99·90
Next lowest in 1915, on October 13	100·05

It is to be noted regarding these individual Low Waters, that the extreme levels as given are due to secondary undulation, which is here very pronounced. Such levels would only continue for a few minutes. The general level of Low Water, which would continue for about an hour, would be a few inches higher.

The highest High Water known at Sydney occurred during the August gale of 1873. Next to this is the exceptional High Water of November 14, 1904. The actual level reached by the water at these dates could not be ascertained.

Datum at Sydney relatively to St. Paul island.—To obtain a comparison between these datums, the average level of Low Water relatively to datum was determined at St. Paul island for the two periods during which the observations were obtained at Sydney. The following results were thus obtained for the margin between the datum and the average level of Low Water in these periods:

St. Paul island, 1901; July 4 to Aug. 6.	Margin	0·90 ft.	Mean:—
" " 1915; July to October.	Margin	0·38 "	0·64 foot.
Sydney, 1901; July 4 to Aug. 6.	Margin	0·70 ft.	Mean:—
" 1915; July to October.	Margin	0·65 "	0·68 foot.

This shows the good agreement of the datums, relatively to the Low-water level. The datum at St. Ann as explained, was made also to agree with the Sydney datum, by means of simultaneous Low-water comparisons during the season of 1915.

Halifax Harbour.

The tide gauge for the observations begun in 1895 was situated on the water front of the Marine department, adjoining the Dockyard which was then under Imperial control. The gauge was equipped for continuous work throughout the year, with heating in winter to keep the tide pipes from freezing up. For tide levels, it was found impracticable to use a tide scale, as the pile wharves settled and rose again nearly a foot when loaded or unloaded. The

tide gauge was therefore set on an independent foundation of piles and rip-rap, with a floating scale, or sight gauge, used for the height readings, its zero being determined with reference to a Bench-mark.

When the tidal investigations were began in 1895, it was found that three datums were in use at Halifax, which were out of accord with each other; the Admiralty datum, the Royal Engineers' datum, and the City datum. The most important of these from a marine point of view is the Admiralty Low-water datum, to which the soundings on the chart of Halifax harbour are reduced. This datum is fixed with reference to a Bench-mark in the Dockyard, and it was defined by the following note on the chart of Halifax harbour: "The soundings are reduced to the level of Low Water ordinary Spring tides, viz., 16·08 feet below a Bench-mark cut near the south-east angle of the Sail loft at the Dockyard." The mark is a chisel line on the masonry with a broad arrow below it, at 3½ feet from the south end of the east wall of the building, which is now known as No. 3 Storehouse.

This datum was adopted from the outset as the zero level for the tidal observations. The height of the tide in the resulting Tide Tables is thus measured from the same plane of reference as the depths shown by the soundings. The level of the tide gauge, during the years of observation, were checked directly from the Bench-mark in the property adjoining, and any changes in elevation at the gauge, due to settlement or other causes, have been carefully allowed for. The zero of the sight gauge was kept for convenience at 1¼ feet below datum, so that any extreme tides might be recorded on the corresponding diagram of the recording instrument; but the elevation of its zero, and the consequent reading of the datum on the scale, was at all times known to the nearest 0·01 of a foot, which enabled the record to be reduced to datum throughout.

Relations between the datums.—The best relation between the other two datum planes was established by Mr. E. H. Keating, when City Engineer at Halifax, from comparisons between twenty-one Bench-marks, which define the City datum and the Royal Engineers' datum respectively. The difference between them, when two exceptional values are discarded, ranges from 1·61 to 1·96 feet; and the average of the nineteen remaining differences is 1·81 feet. The mean value which Mr. Keating finally adopted, places the Halifax City datum at 1·85 feet below the Royal Engineers' datum. This value for the difference has been generally accepted.

An endeavour made by this Survey to obtain a relation between the City datum and the Bench-mark in the Dockyard, gave no satisfactory result. The City Bench-marks in that vicinity showed a want of agreement with each other, and no method of working out the comparisons could be devised to obviate the outstanding discrepancies, which ranged from four inches to a foot.

The elevation of the Bench-mark in the Dockyard was given as 11·05 feet above the Royal Engineers' datum on their plans; and it was so noted also on the chart of Halifax harbour. The datum is undoubtedly intended for Mean Sea level; but when this level was correctly obtained in 1902 from the first four years of continuous record from the Halifax tide gauge, it was found to differ by 1·55 feet from the Royal Engineers' datum. Such an error is inadmissibly large where the range of the tide is only six feet; while the intention that the

datum should represent Mean Sea level is confirmed by their datum at Quebec, where the correspondence is close, as shown by the elevations already given for Quebec.

The attention of the Colonel Commanding the Royal Engineers was called to this discrepancy in 1902, as it appeared probable that the error was in the elevation of this individual Bench-mark. On investigation this proved to be the case, and its true elevation is 12·61 feet, as found by connecting it with four other reliable Bench-marks as established by the Royal Engineers. This brings the datum into good relation with Mean Sea level, as now determined independently from eight complete years of observation by the Tidal Survey.

The relations of the various datums and Mean Sea level, when referred to the one plane of reference, are given in the list below. These relations were first published in 1903, the value for Mean Sea level being then based on four years of tidal observation, and differing by 0·012 from the present value.

	Feet.
Bench-mark in the Dockyard, as described, which defines the Admiralty Low-water datum	16·08
Mean Sea level, as determined from nine complete years of tidal observation	3·49
Royal Engineers' datum, at 12·61 feet below the Bench-mark in the Dockyard, this being the corrected value of 1902	3·47
Halifax City datum, at 1·85 feet below the Royal Engineers' datum, as determined by Mr. E. H. Keating	1·62
Admiralty Low-water datum, and Tidal Survey datum, which is the zero level of the Tide Tables	0·00

This value of Mean Sea level has been adopted as datum by the Geodetic survey, for their levels extending from the Lower provinces to the St. Lawrence and westward. The levels of the Dominion Observatory system, which started originally from the frontier of Maine, are now connected with this accurate determination of Mean Sea level; and it has served as a basis for their shore line from Halifax to Yarmouth, and from Halifax northward.

Tide levels.—The general tide levels at Halifax, and the details of the determination of Mean Sea level, are given below with reference to the Admiralty Low-water datum, which is taken as 100·00 instead of zero to avoid negative values. The relation of this datum to the "Average level of Low Water" was computed from the Tide Tables, to ascertain the margin between the two, in the case of a well-established Admiralty datum. This margin is a guide in deciding upon the datum for new localities. The Tide Tables thus used are quite accurate, as they are based on 13 years of tidal record including four years of old observations between 1851 and 1861, in addition to the more recent observations of the Tidal Survey. The Average levels of High Water at Springs and at Neaps are based upon the same Tide Tables, for comparative purposes.

	Elevation.
Bench-mark in the Dockyard, as already described	116·08
Coping of the Halifax Dry Dock	110·97
Saxby tide of October 5, 1869. Elevation at Halifax as determined in 1876 by Mr. Keating while City Engineer; 7·90 feet above the City datum	109·52

Highest High Water recorded on the tide gauge during the years 1895 to 1902. Occurred during a gale on November 25, 1901	109·35
Highest High Water recorded during the years 1903 to 1906. Occurred January 25, 1905	108·85
Average level of High Water at Spring tides; from the heights in the Tide Tables during the two complete years 1913 and 1914	106·28
Average level of High Water at Neap tides; from the Tide Tables during the same two years	105·31
Mean Sea level; from the hourly ordinates of the tide during nine complete years between November 1895 and July 1906. (See details given below)	103·49
Average level of Low Water at Spring tides; from the Tide Table values during the two years 1913 and 1914, as above	100·54
Admiralty Low-water datum, to which the tidal observations were reduced throughout the years 1895 to 1906. Also the zero level for the height of the tide in the Tide Tables	100·00
Exceptional Low Waters during the years of observation, from 1895 to 1906:—	
In 1903, on January 13; at extreme of astronomical conditions, but not disturbed	98·62
In 1904, on February 2 (ditto)	98·46
In 1905, on February 19; disturbed by storm	98·82
In 1906, on July 6; not disturbed	99·00
Sill of Halifax Dry Dock. Geodetic Bench-mark No. 832, on surface of the sill. Geodetic elevation, 26·99 feet below Mean Sea level	76·50
Surface of the granite sill of the dock. Tidal Survey determination in 1902	76·49

The depth of water on the sill of the dock at any tide, may therefore be found by adding 23·5 feet to the height of High Water as given in the Tide Tables for Halifax.

Mean Sea level at Halifax.—The determinations are from the hourly ordinates of the tide measured from the Admiralty Low-water datum which was maintained throughout the years of observation. Each determination is for a complete year.

	Feet.
One year, from November 1895 to November 1896	3·391
" January 1897 to January 1898	3·515
" January 1898 to January 1899	3·510
" January 1899 to January 1900	3·488
" August 1900 to August 1901	3·544
" June 1902 to June 1903	3·559
" June 1903 to June 1904	3·513
" July 1904 to July 1905	3·427
" July 1905 to July 1906	3·429
Average adopted; above Admiralty datum	3·490

On comparing these values with the determinations at New York during the same periods of 12 months, making up these complete years, the variations correspond exactly. The lowest and highest values occurred in the same years at New York. The extreme variation between the years 1895-'96 and 1902-'03 was 0·168 foot at Halifax, and 0·186 at New York. There can be no doubt therefore that there is an actual variation in the mean level of the ocean, in different years, within such limits. An average value based upon five years or more, may be taken as correct in the absolute, as a basis for extended levelling. Any alteration of the value would indicate an elevation or subsidence of the coast region relatively to the ocean level.

Southern Nova Scotia.

In the season of 1902, simultaneous observations were taken around the southern extreme of Nova Scotia, from Shelburne to Yarmouth. A leading object in these observations was to ascertain the best dividing line between the harbours which can be referred to Halifax and to St. John, N.B., in the two directions. The tide on the whole south-eastern side of Nova Scotia, from Canso almost to Cape Sable, is nearly simultaneous with Halifax, and about the same in its range. At Yarmouth, the tide is distinctly of the bay of Fundy type, and has a very constant time-relation with St. John. The investigations of 1902 made it clear that ports in the vicinity of Cape Sable and eastward can best be referred to Halifax, while from Pubnico westward they can be referred to St. John, N.B. with greater accuracy.

In regard to tide levels, it was not deemed necessary to establish Bench-marks at Shelburne, Barrington passage or Pubnico. At two of these harbours the wharves are of piling and are not liable to settlement; and the zero of the tide scale was fixed with reference to the cap of these wharves. After the tidal record for the season was obtained, the Low-water datum was decided upon, relatively to the Average level of Low Water at Spring tides according to the standard method, and to correspond with the Halifax datum. The tide levels may therefore best be given with reference to this datum. At Clarke harbour, in the immediate vicinity of Cape Sable, a Bench-mark was established, and definite elevations can there be given.

At these localities, even where there are no permanent Bench-marks, the datum line is ruled on the tide diagrams. There is thus a record of the heights and levels of all tides at these localities, with reference to a consistent series of Low-water datums.

Shelburne.—The zero of the tide scale was at 14·12 feet below the cap of the wharf; and the Low-water datum is at 1·80 on the scale.

	Feet.
Cap of wharf above Low-water datum	12·32
Highest High Water in the season of 1902, on October 1	8·60
Average level of High Water at six Spring tides during the season of 1902, from July to beginning of October	7·81
Average level of Low Water at seven Spring tides during the season	0·49
Low-water datum as adopted	0·00
Lowest Low Water in the season of 1902, on July 8 (below datum)	—0·20
Zero of the tide scale of 1902, below the datum as adopted	—1·80

Barrington passage.—This passage lies between Cape Sable island and the mainland. The zero of the tide scale was at 14·42 feet below the cap of the wharf; and the Low-water datum is at 1·65 on the scale.

	Feet
Cap of wharf above Low-water datum	12·77
Highest High Water in the season of 1902, on October 1	9·55
Average level of High Water at seven Spring tides during the season of 1902, from July to October	9·13
Average level of Low Water at the seven Spring tides during the season	0·51
Low-water datum as adopted	0·00
Lowest Low Water in the season of 1902, on October 18 (below datum)	0·15
Zero of the tide scale below the datum as adopted	—1·65

Clarke harbour.—This harbour is in the immediate vicinity of Cape Sable, the extreme southern end of Nova Scotia. The Bench-mark of 1902 is the top of an iron bolt drilled into the rock at 14½ feet from the north-east corner of Swim's warehouse, which is the most northerly of a set of buildings that extend to the Government wharf at Swim's Point.

	Elevation.
Bench-mark as described	100·00
Highest High Water in the season of 1902, on July 5	90·75
Average level of High Water at eight Spring tides during the season 1902, from July to October	89·96
Average level of Low Water at the eight Spring tides during the season	80·06
Low-water datum as adopted, at 0·64 foot below Average Low Water.	79·42
Lowest Low Water in the season of 1902, on July 7	79·20

Summary of Rise and Datum levels.—The following table is based on the simultaneous observations of 1902, from Shelburne to Yarmouth. It [illegible] connects the Atlantic coast with the entrance of the Bay of Fundy [illegible] the consistency of the Low-water datum throughout. The [illegible] the datum and the Average level of Low Water is also in good [illegible] with Halifax, as shown by its value as given in the Halifax tide [illegible]

Locality.	Spring rise.	Extreme difference of level.	Datum below Average L. W. Springs.
	Feet.	Feet.	Foot.
Shelburne	7·81	8·80	0·49
Barrington passage	9·13	9·70*	0·54
Clarke harbour, Cape Sable	10·54	11·55	0·64
Pubnico (at Lower East Pubnico)	12·03	13·20	0·62
Yarmouth, N.S.	14·88	16·20	0·76

* The extreme tides of July were not obtained here, and this value is not therefore truly comparative with the other localities.

Bay of Fundy. (Lower part.)

The special characteristic of the tide in this region is that it is chiefly influenced by the moon's distance. The variation in range with the change in the moon's distance from perigee to apogee, is distinctly greater than the variation from Springs to Neaps. The values of these variations will be given in a comparison of St. John with the head of the Bay of Fundy.

This type of tide is termed anomalistic. It is evident that the two Spring tides of the month will only be equal when perigee and apogee fall at the moon's quarters, as successive Spring tides will then be at the moon's mean distance. When perigee falls at the new or full moon, the two Spring tides of the month will be the most unequal. This semi-monthly inequality, at the head of the Bay of Fundy, amounts to 10¼ feet between the Spring range at perigee and apogee respectively. It is therefore evident that for correct averages the tides must be balanced in this respect; and if an even number of Spring tides is not taken, there must be two which are equal, at the moon's mean distance, before this inequality becomes reversed in the succeeding months. It may be assumed without further explanation, that this care has been taken in the averages which are given; and that different localities are also made as truly comparative as possible.

It is to be noted that where there is no permanent Bench-mark, the datum line is ruled on the tide diagrams. The heights and levels of all tides are thus recorded with reference to a datum which is consistent with others in the region.

Lower East Pubnico.—Observations were obtained here in 1902, in the simultaneous series already referred to, from Shelburne to Yarmouth. The zero of the tide scale was at 17·58 feet below the cap of the wharf, and the Low-water datum as determined from the observations, is at 0·40 on the scale.

	Feet.
Cap of wharf above Low-water datum	17·18
Highest High Water in the season of 1902, on July 5	13·00
Average level of High Water at eight Spring tides during the season of 1902, from July to October	12·03
Average level of Low Water at the eight Spring tides during the season	0·62
Low-water datum as adopted	0·00
Lowest Low Water in the season of 1902, on July 7 (below datum)	—0·20

Yarmouth, N.S.—Tidal observations were begun here with the simultaneous series throughout the Bay of Fundy in June, 1898; and it was found possible to continue them until January, 1905, on account of the mildness of the region, without the complete installation and winter heating which are necessary at all other stations. With some special precautions, there was a loss of record of only one to 2½ months in three of the winters in this period. A total of 24 months of observation, simultaneous with St. John, served as a basis for the difference in the time of the tide; and from four months at the four quarters of the year in 1903, the ratio of the ranges was determined.

The rail level at the railway crossing at the foot of Forrest street was originally taken as 100·00 feet; but for a permanent Bench-mark in the vicinity

of the tide gauge, the brick chimney of the Kemptville Lumber company was selected, as it stands on a stone base built in cement and the foundation is carried down to the rock. The point used as a Bench-mark is the joint between the stone foundation and the brickwork, at the north-west corner.

When it was found in 1904 that this saw-mill was closed and the property might be sold, the levels were carried for greater security to the Post Office building. The Bench-mark is on the north side of the building, at five feet from the corner of Main street; a broad arrow cut on the second course of the sandstone foundation, at 2 feet 3 inches above the sidewalk.

Levels were taken in 1901 and 1902, to obtain the relation between the Tidal Survey levels and the Town datum in Yarmouth; and in this endeavour the Town engineer, Mr. E. S. Matheson, gave his co-operation. The comparisons differ by about two inches, however, as shown by the two here given, which were checked by two similar ones:—

Spindle of hydrant at corner of Cliff and Main streets: elevation above Yarmouth town datum, 141·88. Tidal Survey elevation, 137·31. Difference, 4·57 feet.

Top of stone post at south-east corner of L. E. Baker's office, at head of the Yarmouth Steamship company's wharf; elevation above Yarmouth town datum, 99·54. Tidal Survey elevation, 94·81. Difference, 4·73 feet.

The mean difference is therefore 4·65 feet, which was adopted.

It was possible to use an open tide scale all the year round at Yarmouth, as this is the most southerly region on all the coasts of Eastern Canada. Although the scale was replaced two or three times during the years of observation, its zero was at all times accurately known in elevation, within 0·01 of a foot.

As the primary object of the observations was to obtain time values for Tide Table purposes, the Low-water datum was not decided upon until three years of observation were available as a basis. Some care was also required, as the level of Low Water may differ as much as 2¼ feet at consecutive Spring tides, when the new and full moon happen to fall at perigee and apogee. The relation of the datum to the Average level of Low Water at Spring tides, will be seen in the elevations here given.

At the request of the Dominion Observatory, the value of Mean Sea level at Yarmouth was determined in 1914, from the hourly ordinates of the tide during one complete year of observation, in 1899 to 1900. It was found to be at 7·548 feet above the Low-water datum. This determination, and the value at Halifax deduced from the observations there, were utilized by the Dominion Observatory as a basis for their precise levels on the shore line from Halifax to Yarmouth; the levels being thus correlated at both ends with the true mean level of the sea.

In the tide levels following, the extreme tides in the seasons of 1898 and 1902 are included, for comparison with the simultaneous series at other localities in those years.

	Elevation.
Bench-mark on Post Office, as described	131·89
Bench-mark on chimney of Kemptville Lumber company, as described	108·53
Extreme High Water; the highest recorded on the tide gauge during	

the three nearly complete years of 1901, 1902, and 1903; this elevation being reached within one inch, at some date in each of these years	91·15
Highest High Water during the simultaneous series in the season of 1902, on July 5	90·60
Highest in the summer season of 1898, on July 4	90·45
Average level of High Water at 26 Spring tides during a complete year from July 1899 to July 1900	89·31
Mean Sea level; from the hourly ordinates of the tide during one complete year in 1899 and 1900; 7·548 feet above Low-water datum	82·15
Mean Low Water at Spring tides; being the average elevation throughout the three years 1901, 1902 and 1903, of the two low tides of the day at the Springs; the diurnal inequality and the semi-monthly inequality being both eliminated	75·60
Average level of Low Water at 24 Spring tides during the complete year as above, from July 1899 to July 1900; omitting two disturbed tides	75·17
Low-water datum, adopted in 1905 as 1·00 foot lower than the mean elevation determined, in the manner explained, from the Spring tides of 1901, 1902 and 1903	74·60
Lowest Low Water during the simultaneous series in the season of 1902, on July 7	74·40
Lowest in the summer season of 1898, on July 5	74·15
Extreme Low Water during the three years 1901, 1902 and 1903; occurred in 1901 on April 20	73·95

The rise of the tide at Yarmouth is 55 per cent of the rise at St. John, N.B. This ratio applied to the height in the St. John Tide Tables, gives the rise above the Low-water datum at Yarmouth.

Westport, N.S.—This harbour lies in Grand Passage, on the north side of Bryer island. Tidal observations were obtained here in 1898, from July 7 to November 24. No Bench-mark was established here. The tide levels are referred therefore to the Low-water datum; which was determined relatively to St. John as follows:—

The St. John datum, from simultaneous observations there during the period of the Westport observations, was found to be at 1·63 feet below the Average level of Low Water at Spring tides.

The Low-water datum at Westport was placed at this same distance below the Average level of Low Water at Spring tides there, during the period of the observations, with allowance for the ratio of the ranges. The distance thus became 78 per cent of 1·63, or 1·27 feet.

	Feet.
Highest High Water in the season of 1898, on August 2	20·45
Average level of High Water at nine Spring tides during the season of 1898, from July to November	19·25
Average level of Low Water at the nine Spring tides during the season	1·27
Low-water datum as adopted; at 1·27 feet below the Average level of Low Water	0·00

Lowest Low Water during the period of the observations, on August 31	-0·15
Extreme Low Water as recorded in the later observations of December; on December 15	-0·30

Digby.—Tidal observations were obtained at Digby pier in 1898 from July to December. The only masonry in this vicinity was a flight of granite steps on which a Bench-mark was established; but these were afterwards pulled down. In 1902, a new Bench-mark was placed on the Post Office building, built since 1898; as there were then no masonry buildings in the town. The levels were obtained from reference points on the timberwork of the Digby pier, which were compared with each other and carried to the new Bench-mark. One of these reference points was the top of the cap on north side of pier, where the tide gauge was placed; its elevation being taken originally as 100·00 for convenience in the tide measurements.

Bench-mark on Post Office building: on north side of the tower, at the joint between the granite foundation and the brickwork; marked by a broad arrow cut at upper edge of the granite, at two feet west of basement window in that side of the tower.

	Elevation.
Bench-mark, as described	108·98
Cap at pier at side of gauge in 1898	100·00
Highest High Water in the season of 1898, on July 3	93·90
Average level of High Water at ten Spring tides during the season of 1898, from July to November (two being omitted)	92·35
Mean Low Water at Spring tides; being the average elevation of the two low tides of the day at each of the Springs during the season; the diurnal inequality being thus eliminated	66·54
Average level of Low Water at twelve Spring tides during the season	66·12
Low-water datum adopted as 1·52 below the Average level of Low Water at Spring tides; this value being obtained by comparison with the simultaneous tides at St. John during the season, by the same method as at Westport	64·60
Lowest Low Water in the season of 1898, on August 4	63·70

Range at Digby and St. John.—The proportionate rise of the tide and the range at Digby in relation to the principal tidal station at St. John, N.B. is shown in the following table. The comparison is based upon the Average level of High Water at ten simultaneous Spring tides in 1898, from July to November; and the Average level of Low Water at twelve simultaneous Springs, from July to December. As a result, the rise or range of the tide is 6 per cent greater at Digby. This value is of service, because of the connection of the provinces of New Brunswick and Nova Scotia by the ferry steamships between these ports, on the opposite sides of the Bay of Fundy.

Locality.	Spring rise above datum.	Average L.W. above datum.	Spring range, by difference.	Ratio of Ranges. (Per cent.)
	Feet.	Feet.	Feet.	
St. John, N.B.	26·26	1·50	24·76	100
Digby, N.S.	27·75	1·52	26·23	106

Campobello island.—Tidal observations were obtained at Welchpool, the harbour on the inner side of this island, in 1898. This location, in the extreme Canadian waters adjoining the International boundary, was selected because it was here that the old observations of 1845 to 1847 were obtained, during the original Admiralty chart surveys. This tidal record exists; and although there is no Bench-mark, the limiting levels reached can be given with reference to the tide scale then used, as follows:—

	Feet.
Highest High Water of 1845 to 1847, occurred January 27, 1846; height on tide scale	27·00
Lowest Low Water, occurred December 20, 1846; height on tide scale.	1·40

The extreme difference of level observed was therefore 25·60 feet.

In the observations of 1898 the tide levels are reduced to a Low-water datum determined to accord with the reference station at St. John, N.B. The details may be given as a further example, as it is the method generally used by this Survey, when there is appreciable difference in the range of the tide at the new locality and the reference station.

The St. John datum, from simultaneous observations there during the period of the Campobello observations was found to be at 1·71 feet below the Average level of Low Water at Spring tides.

The ratio of the range at Campobello to St. John, which can be determined without reference to datum, was found to be 90 per cent.

The difference of 1·71 feet at St. John, multiplied by this ratio, gives 1·54 feet; which is the corresponding margin to be taken at Campobello below the Average level of Low Water there, for the Low-water datum.

	Feet.
Highest High Water in the season of 1898, on August 2	23·55
Average level of High Water at eight Spring tides during the season of 1898, from July to October	22·56
Average level of Low Water at the eight Spring tides during the season	1·54
Lowest Low Water in the season of 1898, on August 3	0·05
Low-water datum as adopted; at 1·54 feet below the Average level of Low Water at Spring tides	0·00

St. John, N.B.

This tidal station can be used for reference for the whole Bay of Fundy, and a registering tide gauge has been maintained here since 1894. To maintain an air space around the tide pipes for heating in winter, an open column 35 feet high is required, which carries a pressure of a ton to the square foot at its lower end. The foundation on which it stands is 21 feet below that again. This column was originally built of timber-work; and in 1914 it was renewed in iron and concrete. Owing to the great fire of 1877 the early Bench-marks and other points of reference were destroyed; and when the tidal observations were begun in 1893, there was no means of ascertaining the datum plane used in the original Admiralty survey of the harbour or in the later survey of the entrance to the harbour, made in 1887 by the Public Works department. There was no city datum in use at the time, as the steep slope of the streets was taken advantage of to lay out the city works by difference of level without reference to any one datum plane.

It was therefore necessary to re-determine a Low-water datum, which required care in dealing with a range of 25 feet, by which all the variations of level are much increased. The special feature of the tide in the Bay of Fundy is a varintion in range with the moon's distance which is greater than the variation from Spring to Neaps. Hence when perigee falls at new or full moon, the difference in the level of Low Water at successive Spring tides may amount to three feet.

The plans of the Public Works department for the breakwater at Negro Point show the level of High Water and Low Water relatively to the surface of the planking as 5 feet, and 30 feet 6 inches, respectively. This presumably defines the Public Works Low-water datum. The levels at the breakwater were accordingly carried across the harbour to the tide gauge by simultaneous readings at High Water; and the resulting datum as thus ascertained is given with the present tide levels. The Public Works datum adopted by Mr. E. T. P. Shewen in 1896, and used while he was Resident Engineer, was 8 inches lower than the elevation thus found from the breakwater.

The plane of reference from which the height of the tide in the Tide Tables is mensured, should be placed sufficiently low that few tides in the course of the year may fall below it. In view of the large semi-monthly inequality in the range, it is therefore quite necessary to base the Low-water datum on the average level of the lower of the two Spring tides of the month. After some trial comparisons and corrections, the datum adopted in November 1895 was at elevation 44·40 or 55·60 feet below the Bench-mark on the Custom House building. This datum is appreciably above extreme Low Water, as during the year 1895 by which it was tested when it was adopted, there were six tides that touhced or fell below it. Its relation to the Average level of Low Water as determined by the standard method in which both the Spring tides of the month are included, is shown in the tide levels here given.

This Low-water datum has been maintained constantly since 1895 in the reduction of the observations and as the zero level of the Tide Tables. It was adopted also for uniformity by the Public Works department in 1908. The

recent dredgings in the harbour have altered the depths very generally, and the soundings on the latest chart of St. John harbour are all referred to this Low-water datum, so that the chart datum is now the same as the zero level in the Tide Tables.

The Tidal Survey Bench-mark of 1894, is a broad arrow cut in the granite foundation of the Custom House on the Prince William street front, near the south-east corner. The elevation adopted for this Bench-mark is 100·00 feet. (Elevation in the Dominion Observatory levels, 41·93, and in the Geodetic levels, 42·15.)

Bench-mark 99-B in the Precise levelling of the Dominion Observatory, described as follows: In the foundation stone at the south end of front wall of Custom House, Prince William street. Elevation, by levels connected with the United States system at St. Stephens on the frontier of Maine, 42·722 feet.

Bench-mark MD.XLVIII in the Geodetic Survey series of the Public Works department; a copper bolt set horizontally into cut stone in the front walls of the Custom house, near the south-east corner. Elevation by levels carried from Halifax and based on Mean Sea level there, 44·09 feet.

These two Bench-marks were placed about the years 1909 and 1913 respectively.

	Elevation.
Tidal Survey Bench-mark of 1894, on the Custom House, as described.	100·00
Dominion Observatory Bench-mark 99-B, by difference of elevation, as above stated	100·79
Geodetic Bench-mark MD.XLVIII	101·94
Top of iron cylinder of tide gauge, on which the tide house stands	75·88
Highest High Water observed from 1900 to 1912, occurred in 1900 on March 2	73·50
Average level of High Water at twelve Spring tides during the season of 1898, from June to November	70·63
Average level of High Water at Neaps; from thirteen tides in each of the two seasons of 1904 and 1907, from May to October	67·10
Mean Sea level, from the hourly ordinates of the tide during nineteen complete years of observation, between 1894 and 1915. The value above the Low-water datum varies from 13·835 to 14·151 in different years. Mean, 13·996 feet	58·40
Average level of Low Water at 24 Spring tides, during one complete year from July 1899 to July 1900	46·10
Low-water datums formerly used:—	
Level of Low Water at Spring tides, as determined from the Negro Point breakwater, as above explained	46·34
Public Works datum adopted in 1896 by the Resident Engineer for construction purposes	45·66
Low-water datum established by the Tidal Survey in 1895, being the zero level from which the height in the Tide Tables is measured. Also adopted by the Public Works department	44·40
Lowest Low Water observed from 1901 to 1908; occurred in 1905, on February 21	43·45

Inlet to the tide gauge, at 10 inches above the bottom of the tide gauge cylinder	11·64
Bottom of the foundation cylinder, filled with concrete	20·05

Extreme tides and Low Water datum at St. John.—The various extremes and averages here given, are referred to datum to correspond with the height in the Tide Tables and to show the relation of Low Water to the datum. The datum is at elevation 44·40 feet. The average level of Low Water in the seasons of 1898 and 1902 are given for comparison with the simultaneous observations at other localities in those years.

	Feet.
Highest High Water in 1896, in October and November	28·70
" " in 1900, on March 2	29·10
" " in 1901, on November 26	28·70
" " in 1902, on June 8	28·90
" " in 1908, on February 1	28·70
" " in 1909, on February 20	29·00
" " in 1916, on January 5	28·90
Mean Sea level above datum; average of 19 complete years (13·996)	14·00
Average level of Low Water at 13 Spring tides in the season of 1902, from June to November	1·84
Average level of Low Water at 13 Spring tides in the season of 1898, from June to November	1·68
Average level of Low Water at 24 Spring tides during one complete year, from July 1899 to July 1900	1·70
Mean Low Water at the lower Spring tide in each month during the same year, 1899–1900	0·76
Low-water datum, the zero level of the Tide Tables; at elevation 44·40 in the general tide levels	0·00
Lowest Low Water in 1900, on October 9 (below datum)	—0·75
" " in 1904, on March 2	—0·85
" " in 1905, on February 21	—0·95
" " in 1907, on January 16	—0·55
" " in 1909, on January 24	—0·60
" " in 1914, on April 13	—0·75

As to the frequency of these extremely low tides, in the eight years 1901 to 1908 inclusive, there were only the three Low Waters, above indicated, which fell lower than 0·30 foot below datum.

Variation with the moon's distance.—The large variation in the level of Low Water when the moon's perigee falls at one of the Spring tides in the month and apogee at the other, is here shown as an example. The heights given are above or below the Low-water datum. When this inequality is so large relatively to other variations, it becomes advisable to base the Low-water datum on the average of the lower of the two Spring tides in each month. The level of High Water is similarly affected, and it would be an advantage to distinguish the rise at perigee and apogee Springs respectively, if full Tide Tables were not available. This characteristic of the tide is general throughout the Bay of Fundy.

(At St. John, N.B.) Date, 1899.	Lowest L. W. at Spring tides.	Moon's distance.	(At St. John, N.B.) Date, 1900	Lowest L. W. at Spring tides.	Moon's distance.
	Feet.			Feet.	
July 25	−0·40		Jan. 31	0·80	
Aug. 8	3·30		Feb. 16	3·40	
Aug. 22	−0·10	Perigee.	Feb. 28	0·10	Perigee.
Sept. 7	3·30	Apogee.	Mar. 18	2·25	Apogee.
Sept. 20	0·20		Mar. 31	0·25	
Oct. 7	2·55		Apr. 16	2·60	

Bay of Fundy. (Upper part.)

Towards the head of the Bay of Fundy, from localities where the range exceeds 35 feet, there are no wharves which extend beyond half tide. The numerous small steamers in the upper part of the bay have therefore to make their calls at High Water and leave promptly. Schooners are accommodated by lying on a bench of mattress-work, against the wharves, while the tide is down. For the purposes of navigation, therefore, the most essential information is the time of High Water, as it is only then that wharves can be reached. The observations of 1898 had this special object in view; and a tide gauge placed at the end of a wharf, registering from half-tide upwards, afforded the information required.

As regards tide levels, the extreme at High Water was always obtained, which is valuable for purposes of wharf construction, and also in relation to the protection of the extensive hay lands, known as dyked marshes, around the head of the Bay of Fundy. At the cities of Moncton and Windsor useful tide levels have been obtained, and at two points at the head of the bay, at the ends of its two arms, complete levels including Low Water have been obtained, by which the extreme range of the tide has been definitely ascertained, as well as its features and characteristics, and its variations in accord with astronomical conditions. This information is fully given in a publication entitled "Tides at the Head of the Bay of Fundy," with tables and map; issued in 1916.

The simultaneous observations of 1898, in the upper part of the bay above St. John, were obtained at Hopewell cape, opposite Folly Point in Chignecto channel, from July 30 till November 15; and at Moncton from August 10 till November 18. Also, in the eastern arm of the bay, at Parrsboro pier from July 22 till October 14, and at Windsor, N.S. from August 16 till November 18.

Moncton and Windsor are so far up the rivers on which they are situated that the lower levels of the tide are cut off by the river slope, and the tide does not fall to true Low Water. At the other two localities the Low-water line is far beyond the end of the wharves, and is of little concern to navigation. With regard to the complete range of the tide, and its variations at both High and Low Water, the data have been obtained at the extreme head of both arms, and will be given concisely further on.

For practical purposes therefore, next to the time of High Water, which is the chief essential for any navigation, the important matter is the variation in the level of High Water at different times in the month; as this affects the

question of the available draught for vessels. The extreme tide levels around the head of the bay are also of essential importance to the agricultural interests, in the protection of dyked lands. These extremes have been observed for a number of years by this Survey, at Sackville harbour, Fort Lawrence dock and Amherst harbour in Cumberland basin, where they are definitely referred to Bench-marks; and the results will be summarized herein.

Variations in the level of High Water.—These variations, as read simultaneously on the four independent tide scales during the season of 1898, are given in the table below. The average level of High Water at the Spring and Neap tides respectively, was determined from the mean of two consecutive High Waters at each of the Springs and Neaps throughout the season, to eliminate diurnal inequality. The difference between these average levels is given in the first column. The greatest and least heights in the next two columns are simply the greatest and least scale readings at High Water at the various localities. Although the zeros of these scales have no relation to each other, the readings show the large variation; and the last column gives the extreme difference in the High-water level as observed during the season.

Locality, in Season of 1898.	Difference in Average level of High Water at Springs and Neaps.	Greatest height of High Water at Springs.		Least height of High Water at Neaps.		Extreme difference in H. W. level.
	Feet.	Date.	Feet.	Date.	Feet.	Feet.
Hopewell cape	6·17	Aug. 3	14·95	Sept. 10	3·50	11·45
Moncton	6·36	Aug. 31*	28·40	Sept. 10	17·10	11·30
Parrsboro pier	6·04	Aug. 3	20·65	Sept. 10	10·70	9·95
Windsor	5·86	Sept. 1	12·65	Oct. 8	2·55	10·10

*The tide of August 3, not obtained at Moncton, was probably half a foot higher than this; as indicated by the difference at Hopewell cape on these two dates.

Moncton, N.B.—Tidal observations were obtained here in 1898, from August 10 to November 18. The registering gauge was placed at Dunlap's wharf, at the foot of Pleasant street. The tide column was attached to the side of the wharf, and continued down 12 feet into the ground as a tide well, made of 12-inch iron pipe. The tide emptied and filled this well by siphoning; and by this method the time of arrival of the Bore was obtained, in the night as well as in the day time.

For the tide levels, the Moncton City datum was made use of; which had been carefully established and referred to Bench-marks by Mr. G. W. McCready, while City Engineer. To avoid negative values however, in extending the elevations to include tide levels, 100 feet is here added to the City elevations; in the same way as at Sydney and Halifax.

City Bench-mark; the surface of the stone door-sill of the City Building, at east side of the entrance, where not worn. City elevation, with 100 feet added, 128·16. Elevation in the Geodetic levels, 35·32.

City Bench-mark; on a brick building with stone foundation, at south-east corner of Duke and Main streets, diagonally opposite the Post Office. The point used as a Bench-mark is the top of the stone foundation at the corner of these streets; which is about an inch above the level of the sidewalk. Used for reference in 1898 for the tide levels. City elevation, with 100 feet added, 133·54 Elevation in the Geodetic levels, 40·70.

Public Works Bench-mark, at the front end of the Sugar Refinery; the surface of the stone door sill at east side of the eastern entrance. City elevation, with 100 feet added, 119·33. (The elevation of this Bench-mark above the Public Works datum is 101·27; High Water at ordinary Spring tides being taken as 100·00 feet.)

	Elevation
Bench-mark as described, corner of Duke and Main streets	133·54
The Saxby tide at Moncton; which occurred October 5, 1869	126·10
Exceptionally high tide of October 12, 1887; as marked by the Harbour master	119·65
Exceptionally high tide of October 8, 1896; from levels taken by the Intercolonial railway Engineers, by request of this Survey. (This tide broke over the dykes along the Petitcodiac river, below Moncton.)	118·90
Highest High Water in the season of 1898, from August to November; on August 31	117·05

Tide levels adopted by the Public Works department for construction of wharves:—

High Water Spring tides (P.W. elevation 100·00)	113·36
High Water Neap tides (P.W. elevation 90·50)	108·56
Cap of Dunlap's wharf, at south-west corner. Elevation in August, 1898	118·98
Bottom of the tide well of the gauge	88·66
Lowest Low Water during the season of 1898, on October 20	87·80
Extreme Low Water, opposite the mouth of Hall's creek; as determined by Mr. McCready while City Engineer	87·75

The full range of the tide is not obtained at Moncton, as it is so far up the river that Low Water is cut off by the river slope.

Parrsboro pier.—The Bench-mark to which the tide levels of 1898 were referred is a chisel line with a broad arrow below it, cut on the south wall of a small stone building, formerly used as a school, at that date used as an ice-house; situated as follows: At 290 feet from shore end of pier, along the main road leading northward to the town of Parrsboro, a cross road turns westward; the building being on the north side of this cross road, at 200 feet along it from the corner. Geodetic elevation of this Bench-mark, 67·24 feet.

A beach of course gravel which slopes back on the landward side, extends in a wide sweep from the pier to Partridge island. As it is overflowed at extreme tides, its elevation is given to indicate the level that High Water may reach.

	Elevation.
Bench-mark, as described	100·00
Top of cap of pier, at shore end	57·02
Top of cap at outer end of pier, in 1898	52·55
Extreme High Water, which overflows the greater part of the pier. Highest level reached as pointed out by a summer resident who had occupied a cottage close to head of pier, for several seasons	56·70
Top of gravel beach, as described	56·30
High tide which overflowed the pier in July, 1898; as marked at the time by the crew of a local steamer	55·53
Highest tide recorded by the gauge in the season of 1898, on August 3	54·80
Mean High Water at Spring tides; being the average elevation of the two high tides of the day at each of the Springs during the season; the diurnal inequality being thus eliminated	52·97
Mean High Water at Neap tides; determined in the same way	46·93
Lowest level recorded by the tide gauge	34·15
Surface of beach at outer end of the pier; dry at Low Water	18·25
Low Water at Spring tides, on July 23; observed while gauge was being erected	14·53

According to the best information, the level of extreme Low Water is about five feet below this Spring tide of July 23. The difference between this level and extreme High Water, would thus give 47 feet for the extreme range at Parrsboro.

Windsor, N.S.—Two Bench-marks were established here in 1898; and their elevations were subsequently obtained with reference to the datum of the Midland railway.

Bench-mark A. On the Wilcox building, on the south-east side of Water street. The point used as a Bench-mark is the top of the cut sandstone plinth, on the Water street front, at the end of the building next Gerrish street; being the joint between the sandstone and the brickwork above. Elevation above Railway datum, 158·43 feet.

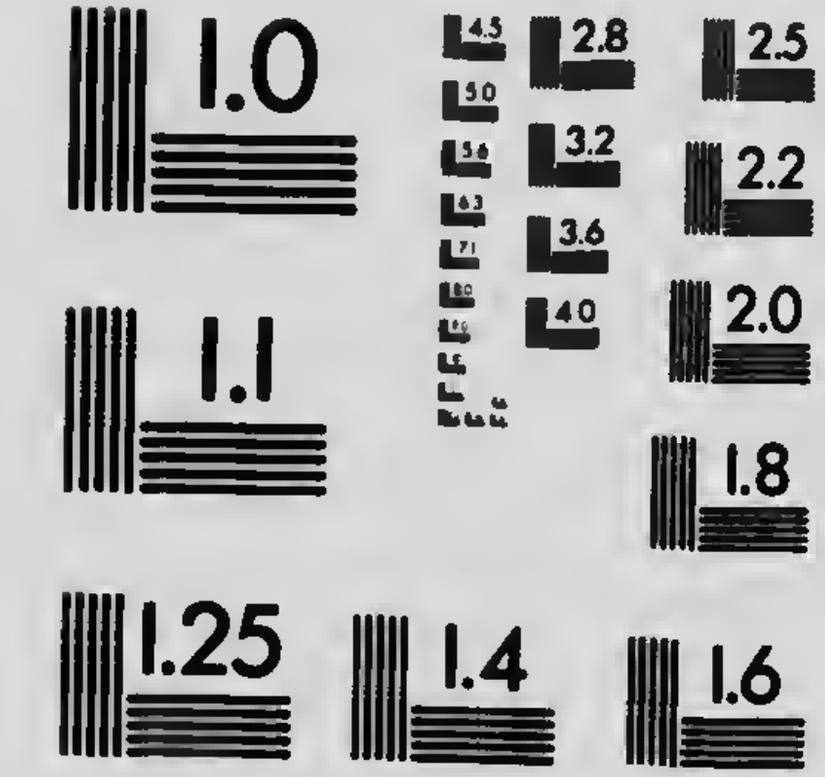
Bench-mark B. On the brick building of W. H. Roach & Co. on the north-west side of Water street, directly opposite the above. The point used as a Bench-mark is the top of the grey granite plinth, at the east corner of the building, below the brickwork. Elevation above Railway datum, 158·46.

The buildings above described were burnt in the previous autumn of 1897, when the town of Windsor was destroyed by fire; but as they have been rebuilt on their old foundations, it is not likely that there will be any settlement to affect these Bench-marks.

	Elevation.
Bench-mark A, as described	100·00
Bench-mark B, as described	100·03
Cap of wharf, at side of tide gauge	95·19
Highest High Water in the season of 1898, on September 1	93·70
Mean High Water at Spring tides; being the average elevation of the two high tides of the day at each of the Springs during the season; the diurnal inequality being thus eliminated	92·10
Mean High Water at Neap tides; determined in the same way	86·24

MICROCOPY RESOLUTION TEST CHART

(ANSI and ISO TEST CHART No. 2)



APPLIED IMAGE Inc

1653 East Main Street
Rochester, New York 14609 USA
(716) 482 - 0300 - Phone
(716) 288 - 5989 - Fax

Lowest level recorded by the tide gauge	81·07
Surface of mud beach in front of the wharf; at much the same level as at the other wharves along the water front	80·00

Cumberland Basin.—An excellent datum for reference in this region was established during the surveys for the Baie Verte canal, in 1870; and the same datum was adopted for the Chignecto Marine Transport railway, which was never completed. These schemes were both intended to connect the navigation in Northumberland strait with the head of the Bay of Fundy for through transportation.

The datum is defined by the level reached by the Saxby tide which occurred in the autumn before the surveys of 1870. It occurred at 1 a.m. on October 5, 1869, and was an exceptional storm tide which flooded the country, as the extensive dyked marshes in this region cover many square miles. The datum is defined as 100·00 feet below this extreme level; that is, the height reached by this exceptional tide is taken as elevation 100·00 in the system of levelling. This datum is an unusually valuable one, as similtaneous tidal observations were obtained during five months in the season of 1870 at Cumberland Basin and at Baie Verte on the two sides of the isthmus of Chignecto, which are both reduced to this same datum. They thus afford a comparison between a tide with 7 feet range on the one side of the isthmus and nearly 50 feet range on the other. The observations consisted of levels only, the time of the tide being ignored. They were also limited to the day time, and only one High Water is obtained on each day, together with a few levels of Low Water during the course of the month. Such levels require care in their reduction to avoid misleading results; but the method of dealing with the diurnal inequality will be explained.

These observations were originally published as an Appendix to the report on the proposed Baie Verte Canal, by the Public Works department, dated April 12, 1873. They have now been republished in "Tides at the Head of the Bay of Fundy," issued by the Tidal Survey in 1916; where the data regarding the features of the tide to be deduced from them, are fully worked out.

At the southern end of the Marine Railway there is a large excavation for the terminal lock, named in the reports the Fort Lawrence dock, with an engine-house beside it for the pumping station. During the tidal observations of 1898, the Bench-marks in this vicinity, by which the Marine Railway datum is fixed, were examined. They are on masonry culverts under the railway roadbed, and with the help of the original working profiles they were located and their elevations ascertained. The stone of these culverts is of a soft nature, however; and by 1901 it had become so much weathered that the Bench-marks were difficult to find, even with the full description which was noted on the ground in 1898. Also, the difference in elevation of the two best of them, which are within half a mile of each other, was found to have altered, being apparently due to the cracking and settlement of the masonry of the culverts on which they are cut. This difference of elevation on the profiles was 3·44 feet, but in September 1898, the actual difference in level proved to be 3·41 feet; and in September 1901, it was 3·39 feet as shown by levels run three times from one to the other. Values were accordingly adopted for them to average this

discrepancy, then amounting to 0·35 foot; and the average value thus obtained was used in establishing a new Bench-mark, which was cut on the engine-house at Fort Lawrence dock. This was further connected in 1913 with the recent Bench-marks on the main line of the Geodetic survey, running through this region; and the valuable datum for the tide levels of the Baie Verte canal and the Chignecto Marine Transport railway will now be preserved without peradventure for the future.

It was desirable to continue observations of the extreme levels which the tide might reach in different years; and as Fort Lawrence dock is an uninhabited locality, there was better opportunity at Sackville harbour, near the mouth of the Tantramar river, in the vicinity of the railway station. Accordingly, in 1901 the Marine Railway datum was carried around the head of Cumberland basin to Sackville, a distance of nine miles, by means of instrumental levels run by the Tidal Survey. Several intermediate Bench-marks were established on this line, as described in the Report of Progress of December 6, 1901. The terminal Bench-mark at Sackville was placed on the masonry foundation of a dwelling-house, and was afterwards transferred to the new masonry railway station, when this was built. When the precise levels of the Dominion Observatory were available in 1914, the difference between the Bench-marks at Sackville and Fort Lawrence dock was corrected by 0·05 foot, to accord with them. This correction is made in the tide levels at Sackville relatively to the Marine Railway datum as defined by the Bench-mark at the dock.

When wharves were built in the mouth of the Laplanche river, which is known as Amherst harbour although some miles from the town of Amherst, a Bench-mark was established there also; and the elevations of some extreme tides have thus been obtained from observations by the Harbour master.

In the information for this region, we may limit the tide levels to a series of the same character as for the other localities around the Bay of Fundy. Amongst the Bench-marks described, two of the Geodetic series are included. The tops of the dykes in the region are also given, as found in the extended levels of 1901, to show their elevations relatively to the extreme level of High Water.

Tidal Survey Bench-mark at Fort Lawrence dock; established in 1901 to preserve the original datum of the Marine Railway. On the north end of the engine-house beside the dock; a step-notch cut in the string course of sandstone at the foot of the westerly of the two middle brick pillasters. It is 5 inches long, and level with the edge of the champfer of the string course. Elevation according to precise levels of the Dominion Observatory, 29·095 feet above Mean Sea level, in their series of elevations.

Bench-mark at Amherst harbour, at the head of the outer wharf. A small square cut on the south end of the coping of a masonry culvert, about ten feet from the shore end of the wharf. The figures 95·57 are cut on the stone beside the mark, which is its elevation above the Marine Railway datum.

Geodetic Bench-mark C.M. At the intersection of the Chignecto Marine Railway with the Intercolonial. On a culvert under the Marine Railway and parallel with the track of the Intercolonial Railway on its west side, at 525 feet south of Fort Lawrence station; a copper bolt in the north face of the culvert,

3½ feet below base of rail. Geodetic elevation, 26·40 feet. Dominion Observatory elevation, 26·60 feet.

Tidal Survey Bench-mark at Sackville. On the masonry Railway station building; the surface of the granite sill of the middle door at the back, or east side, of the station; the north end of the sill marked by an inverted broad arrow cut on the side of the door, with the letters " B. M." above it.

Geodetic Bench-mark, M.CCCC.XXXVI. On the Sackville station building; a copper bolt set horizontally into the east end wall, and marked with the above number. Geodetic elevation, 27·21 feet.

	Elevation.
Tidal Survey Bench-mark of 1901, on the Engine-house at Fort Lawrence dock, as described	101·42
Saxby tide of October 5, 1869; defining the datum of the Baie Verte Canal and the Chignecto Marine Railway, as 100 feet below it	100·00
Bench-mark at Amherst harbour, as described	95·57
Geodetic Bench-mark C.M. near the Fort Lawrence station	98·93
Tidal Survey Bench-mark at Sackville, on the station building, as described	99·02
Geodetic Bench-mark M.CCCC.XXXVI. on the Sackville station building	99·72
Average level of top of dykes around Cumberland basin. (See details in table given.)	97·38
Exceptional High Water of August 1908 (probably Aug. 12). From the level reached by the water at three points near the wharf at Sackville; mean elevation	96·83
Exceptional High Water of September or October 1906; at noon on a calm day. As marked at Amherst harbour	96·73
Highest High Water at Fort Lawrence dock during the observations of the Baie Verte Canal survey, from August to December, 1870. Occurred on October 25 at Spring tides during a S.W. gale	96·00
Next highest in that season, undisturbed by storms, on September 27	94·60
Mean High Water at Spring tides; being the average elevation of the two high tides of the day at six Springs in the later part of the season; the diurnal inequality being thus eliminated	91·22
Mean level of High Water throughout the month; based on a period of four lunar months during the observations of 1870	89·26
Mean level of Low Water throughout the month, during the same four lunar months	52·29
In these two mean levels, the inequalities during the month are averaged, by taking even lunar months; but the diurnal inequality is not fully balanced out, as the observations were in the day time only.	
Mean Low Water at Spring tides; being the average elevation of the two low tides of the day at four Springs in the later part of the season; the diurnal inequalty being thus eliminated	50·21
Reference level taken as extreme Low Water, to which the Marine Railway soundings are reduced. (Defined as 2·75 feet below " Ordinary Low Water " at elevation 50·00, as adopted by the Baie Verte Canal survey)	47·25

Lowest Low Waters observed during the five months in 1870; on October 26 and November 24 (excepting one during a gale).....	47·00
Low-water datum, determined with relation to the St John datum by the general method already explained, based on the tides at St. John as specially calculated for 1870.....	46·98

In the values above given for mean High Water and mean Low Water at Spring tides the diurnal inequality is eliminated by computing the elevation of the missing night tides from their corresponding values at St. John, in the tide tables calculated for 1870. In the values for the mean level throughout the month, the diurnal inequality is not fully eliminated, as explained. In both cases however, the large semi-monthly inequality is carefully eliminated by the methods employed. This inequalty is due to the difference between perigee and apogee Springs, and it may occasion a difference in level of 5 to 6 feet in either High Water or Low Water at successive Spring tides. With these explanations, we may proceed to make a comparison of the Half-tide level, based on the best data which the observations afford, with the values of Mean Sea level carried from Halifax by the recent systems of precise levelling.

Mean Sea level.—The values at the head of the Bay of Fundy and in Northumberland strait, on the two sides of the isthmus of Chignecto, are given below. They are based on the elevations of the Bench-marks already mentioned, and on the tide levels above stated.

	Elevation.
Mean Sea level, according to the precise levels of the Dominion Observatory; based on the determination at Halifax by the Tidal Survey. (From their elevation for the Bench-mark on the Engine-house at Fort Lawrence dock.).....	72·33
Mean Sea level, according to the levels of the Geodetic Survey; based also on the Halifax determination. (From the elevation of Bench-mark C.M. as connected with the Marine Railway datum.).....	72·53
Half-tide level in Cumberland basin; between mean High Water and mean Low Water throughout the month, determined as above explained.....	70·77
Half-tide level in Cumberland basin; between mean High Water and mean Low Water at Spring tides, determined as above explained..	70·71
Half-tide level at Tidnish, Baie Verte; from 48 days on which both High Water and Low Water were observed, between August and December, 1870.....	71·18

The divergence in Cumberland basin from the oceanic value of Mean Sea ., may be due to variations which are not completely eliminated; as the Low Waters observed are so incomplete, there being only 13 per month on the average. It is also possible that the tide curve may be modified in the direction of the estuary type, and be unsymmetrical. In the other arm of the Bay of Fundy however, in Cobequid bay, where the form of the tide curve was accurately determined, it proved to be strictly symmetrical.

The correspondence is sufficiently near in any case, to show that Mean Sea level at the head of the Bay of Fundy is closely the same as in the Gulf

of St. Lawrence and the Atlantic. This means that the heavy tidal pulsation at the head of the bay, is equally above and below the true standing level of the sea, if there were no tide. It would appear also that in storms, the level falls as much below ordinary Low Water as it raised above ordinary High Water. It is estimated that the Saxby tide fell to elevation 42·50, which from the extreme high of 100·00 would make its mean level 71·25; which compares closely with true half tide.

Level of the top of the dykes.—The dykes are built to reclaim the extensive 'marshes' or hay lands between Amherst and Sackville on Cumberland basin, Bay of Fundy. The elevation given in each case is the average level of several points on the dyke. The relation of the dyke level to extreme High Water will be seen on comparing these levels with the elevations already given.

We may note with regard to these dykes the great uniformity in level throughout the stretch of nine miles in extent. This can only have been arrived at from the level of the water itself when standing at high tide. The level as now determined will be valuable for future reference, and also in establishing the relation of the dyke level to extreme High Water.

	Elevation.
Dyke on east side of Missiquash river, at its mouth	97·26
Dyke on west side of Missiquash river, at crossing of Intercolonial railway	97·14
Dyke on east side of Aulac river, at Aulac station, Intercolonial railway	97·13
Crest of batardeau on which Intercolonial railway crosses Aulac river	97·33
Dyke on west side of Aulac river, at same locality	97·11
Dyke on north side of Aulac river, about 1,000 yards from Intercolonial railway track	97·35
Dyke on north side of Tantramar river, half a mile east of railway bridge	97·64
Dyke at same locality, protecting railway track. (About nine inches higher than other dykes.)	(98·38)
Dykes in same vicinity, general level to horizon	97·82
Dyke on north side Tantramar river, at crossing of Intercolonial railway	97·56
Dykes on Tantramar river, opposite Sackville, general level to horizon	97·44
General average level of top of dykes (omitting the special dyke along the railway)	97·38

Baie Verte.—Observations were obtained at the northern end of the Chignecto Marine Transport railway, at Tidnish in Baie Verte, in 1870 from August 11 to December 29, simultaneously with those in Cumberland basin. The resulting tide levels are given here; as they are reduced to the same datum, in the Report on the Baie Verte Canal, already referred to.

	Elevation.
Highest High Water in the season of 1870, on December 29	77·94
Mean level of High Water throughout the period of the observations	74·00
Half-tide level from 48 days on which both High Water and Low Water were observed	71·18
Mean level of Low Water throughout the period of the observations	68·35
Lowest Low Water in the season of 1870, on September 30	66·86

Cobequid bay.—This forms the head of the eastern arm of the Bay of Fundy, in the direction of Truro. The vicinity of Burntcoat head and Noel bay is as far up the arm as the tide can be measured at any one point, as above this there are sand bars which cut off the full range of the tide. There were old observations at Noel bay, taken in 1859 during the Admiralty chart surveys, for ten days in the month of June; but no extreme tides were obtained because the astronomical conditions were not favourable, the one Spring tide observed being near the moon's apogee. A careful comparison with the Cumberland basin observations, under similar astronomical conditions, enabled the relative ranges to be obtained as a ratio; which indicated that the range at Noel bay was 12 to 19 per cent greater than in Cumberland basin. There was thus every reason to believe that the extreme range of the Bay of Fundy was to be found in this arm.

In planning for observations here in 1916, a month was selected in which perigee would coincide with the new or full moon. The moon being thus nearest at one of the Spring tides would be furthest at the other, and the greatest difference between them would be obtained, as well as the extreme range at perigee Springs. These conditions occurred in June and July; and during observations from June 14 to July 19 two perigee Springs were obtained and one apogee Spring.

Although there is a wharf in Noel bay, little was to be gained by placing a registering tide gauge there, as less than the upper half of the tide would be obtained; and the bay was very unsuitable for instrumental levels, with a full mile from the wharf to Low Water over a stretch of deep mud and quicksand. At Burntcoat head, three miles to the westward, the beach narrows to less than half a mile between High Water and Low Water, and it is mostly sloping rock, with the deep mud confined to coves near High Water. The point selected for the observations was a little cove in the cliffs immediately west of the light-house on the head.

The observations consisted of direct instrumental levels, and readings on tide scales erected on the shore to take in the variations at High Water and Low Water. These were all reduced to a uniform datum, based on a Bench-mark near extreme High Water, for which an elevation of 100·00 feet was taken. The true Low-water datum, relatively to the St. John datum, was based upon a comparison of 23 of the lower Low Waters as observed simultaneously.

As the higher tides rose a few feet against the cliffs at Burntcoat head, the best place that the marks of the extreme tides of the year could be obtained was at the mouth of a stream in Moose cove, about a mile westward. To obtain their elevations, instrumental levels were carried there.

The level reached by the Saxby tide of 1869, was remembered by old residents with reference to the ruins of a house on the bank of Noel river, on the eastern side of Noel bay. The elevations established at Burntcoat head were transferred to Noel river by simultaneous observations of High Water on a calm day, which enabled the elevation of the Saxby tide there to be ascertained.

	Elevation.
Primary Bench-mark; a small square cut on the rock, about the level of extreme High Water. Elevation adopted	100·00
Reference Bench-mark; top of iron bolt set in the rock on west side of the cove	96·33
Reference Bench-mark; top of iron bolt set in the rock on east side of the cove	94·84
Saxby tide of October 5, 1869; as determined from the level reached at a ruined house on bank of Noel river	103·18
Extreme High Water in autumn tides; from average of three well-defined marks at mouth of stream, Moose cove	100·13
Top of dyke across valley of stream at Moose cove; said to be just level with extreme High Water. Average of three points on it	100·10
Highest High Water during the observations of 1916; at perigee Spring tides on July 17. From wash left by the night tide, levelled in next day	99·86
Mean High Water at Spring tides; being the mean elevation at the perigee and apogee Springs, based on the average of the two tides of the day at each of the three Springs observed; the semi-monthly and diurnal inequality being both eliminated	96·18
Mean Low Water at Spring tides; being the mean elevation at the perigee and apogee Springs, determined in the same way	50·84
Low-water datum, determined with relation to the St. John datum by the general method already explained, based on similtaneous observations at St. John	46·85
Lowest Low Water during the observations of 1916; at perigee Spring tides on July 16. Obtained by instrumental levels	46·32
Lowest at perigee Springs in June; on June 17	46·69

Variations in the level of the tide.—The extreme variations in the level of High Water and Low Water, as observed in 1870 in Cumberland basin and in 1916 in Cobequid bay, are shown in the table below. The variations of High Water are comparable with those already given for the other localities in the upper part of the Bay of Fundy; and we are here able to include Low Water also, which was not observed elsewhere.

The elevations are from the same datums as already used, which are quite independent and not correlated with each other; but the differences show the amount of the variations.

The greater differences in Cumberland basin are apparently due to the longer period of observation than in Cobequid bay; in which greater variation would naturally occur. In the values for Cumberland basin, two extremes during storms have been omitted.

Localities at Head of Bay of Fundy.	At High Water.			At Low Water.		
	Highest elevation at Springs	Lowest elevation at Neaps.	Extreme difference in level.	Lowest elevation at Springs.	Highest elevation at Neaps.	Extreme difference in level.
	Feet.	Feet.	Feet.	Feet.	Feet.	Feet.
Cumberland basin.....	94·60	85·00	9·60	47·00	57·30	10·30
Cobequid bay.....	99·86	91·60	8·26	46 32	55·17	8·85

NOTE ON EXCEPTIONALLY HIGH TIDE; AUTUMN OF 1917.

High Water of October 1, 1917, at noon; during a gale which was south-westerly at the head of the Bay of Fundy. Occurred at the Spring tides with moon in perigee. From levels taken by the Tidal Survey in November.

At Moncton. From points marked by the Harbour Master, 19·35 feet above Moncton City datum, or 119·35 in the Moncton series of elevations. (The tide at the next perigee Springs, at 1 a.m. on October 31, came within an inch of this height.)

At Windsor. From the wash of the tide as marked at two points; mean elevation, 95·90 feet, in the Windsor series.

At Sackville. From a point marked by the Harbour Master; elevation above Chignecto Marine railway datum, 97·30 feet.

At Amherst harbour. From measurement made at the time, elevation above Marine railway datum 97·10.

The level reached by this tide at Sackville and Amherst harbour was practically at the top of the dykes in this region, which are at elevation 97·38 on the average. The waves in addition to the true water level, caused many breaks and much damage. (The tides at the next perigee Springs of October 31, though nearly as high at Moncton, were not so extreme at Sackville and [illegible]st.)